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FUNDAMENTAL STUDY OF BIO-FERTILIZERS

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CHAPTER 1

A STUDY ON FORESTRY USE OF BIO-FERTILIZERS

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ABSTRACT:

The forest biomes not only serve as carbon sinks and habitats for biodiversity, but they also prevent soil erosion, lessen climate change, and provide vital resources like fuel, timber, and bioproducts. However, due to a variety of human activities, forest production has drastically decreased over time. In order to combat phytopathogens and nutrient shortages, chemical products are utilized in plantation forests, natural stands, and forest nurseries. However, this often leads to nutritional losses via leaching, gaseous losses, and other unfavorable effects. The use of Bio-fertilizers may promote the expansion and growth of various tree species, which would ultimately increase forest productivity in a more sustainable manner. The bulk of biofertilizer uses, with the exception of mycorrhizae, are focused on the agriculture and horticultural industries, with less attention on forests. Understanding the many methods by which these fertilizers function is crucial for maximizing their potential to provide ecosystem services in forest biomes. As a result, this chapter examines the efficiency of microorganisms in Bio-fertilizers, factors that affect how effectively they perform when applied, and their application in the forestry business.

KEYWORDS:

BioFertilizer, Biocontrol, Forestry, Nitrogen Fixation, Microorganisms, Mycorrhizae, Phytohormones.

INTRODUCTION

The forest biomes are significant internationally because they include more than three trillion trees and span 30% of the planet's land area. Providing biodiversity, preserving soil quality, functioning as carbon sinks, and creating a variety of products including wood, timber, biomass, and coal are just a few of the benefits provided by forests. The boreal, temperate, and tropical zones all have a variety of forest habitats. Some forest ecosystems' distributions are strongly influenced by soil fertility and land use, with nutrient-poor soils being designated for forests and high fertility soils being used for agricultural crops and grasslands. Because of the rapid increase in human and animal populations, forest fires, and the careless use of forest resources, forest productivity has been declining. These human activities have caused ongoing soil erosion, which has resulted in nutritional deficits in the forest soils[1].

Comparatively speaking, the use of chemical fertilizer in the forestry industry from forest nurseries through plantations and natural stands ranges from nil to very little. Fertilizers are normally only sprayed once, or at most a few times, throughout a cycle on the field that lasts 25 to 30 years. When necessary, chemical fertilizer may be used to improve planted forest production, control nutrient deficits in marginal soils, and/or maintain sustainable soil nutrients after several rotations. However, using chemical fertilizers has several disadvantages. In the first place, overuse in the field may result in nutrient losses via leaching, gaseous losses, and diminished beneficial forest microbiomes. Additionally, it is challenging to fertilize forest soils since many woods are inaccessible, sparsely fertile, and distant. Therefore, it is more practical to use the potential of Bio-fertilizers to lessen the dependency on chemical fertilizers in order to support the growth and development of tree species and, in turn, enhance sustainable forest production.

Bio-fertilizers are substances that include helpful microorganisms, mostly bacteria and fungus, which may live in the rhizosphere and/or within plants and then boost plant development when applied to soil, seeds, and/or plants. These microorganisms, also referred to as plant growth promoting microorganisms, can increase plant growth directly by facilitating nutrient uptake in plants and modulating phyto-hormones, as well as indirectly by reducing the inhibitory effects of phytopathogens and improving the rhizosphere for plants and other beneficial microorganisms. While the use of Bio-fertilizers in forestry is still being researched or is only permitted in forest nurseries, with most studies concentrating mainly on mycorrhizae, it is more extensive and common in agriculture and horticulture. In order to fully utilize the potential of bio fertilizer in promoting the growth of tree species, whether it be in forest nurseries, plantations, and/or natural stands, it is imperative to investigate other advantageous microorganisms and their mechanisms of action[2].

Mechanisms of Bio fertilizer Action

In forest biomes, Bio-fertilizers may enhance plant health and development as well as the nutrition and fertility condition of the soil. However, a number of extrinsic variables, such as the qualities of the soil, the type of the trees, and the makeup of the local microbiome, might have a significant impact on how effective the bio-fertilizers are. Because of this, it's essential to comprehend how PGPMs used in bio fertilizer work so that you can use them appropriately. In practice, many PGPMs are likely to use more than one mechanism, either concurrently or at different times and under various circumstances. The potential of PGPMs to give phytoprotection and assist with nutrient absorption are some of their action mechanisms.

Support for N Acquisition

Since nitrogen is a key component of nucleic acids, membrane lipid, amino acids, proteins, chlorophylls, and enzymes, it is essential for plant growth and development. N, on the other hand, is a crucial component that limits growth in forest biomes, particularly in ecosystems that have grown on marginal soils. Despite the fact that N is abundant in the atmosphere as N2, most plants are unable to use it and must rely heavily on the organic and inorganic N forms of soil N bioavailability to support their development. However, with the help of N2-fixing microorganisms, N2 may be transformed into inorganic forms, such ammonium and nitrate, via a biological N2 fixation process that consumes a lot of energy and is catalyzed by nitrogenase. There are two types of nitrogen-fixing bacteria found in forest biomes: There are symbiotic and non-symbiotic N2 fixers. However, compared to non-symbiotic N2 fixation, symbiotic N2 fixation contributes to the bulk of the fixed N needed by plants. Associative N2 fixation is sometimes referred to as symbiotic N2 fixation since it meets the concept of symbiosis, which is a beneficial interaction between two separate species. However, most literature refers to symbiotic N2 fixation as symbioses with the establishment of root nodules. But for the purposes of this review, the earlier definition will be used.

Mutualistic N2 Fixation

According to studies, the interaction between legumes and rhizobia is a major contributor to the quantity of fixed N2 in many forest biomes. Many tree legume species, though not all, have the capacity to fix atmospheric N2 in conjunction with rhizobia, a collection of gram-negative bacteria that may produce N2 nodules on mostly legume roots when N levels are low. Rhizobia may enter leguminous root tissues by epidermal, crack, or hair infection. The majority of legumes use the root hair infection strategy, in which flavonoids secreted by the plants tell rhizobia to release signal molecules that bind to root hair cell receptors, causing the root hair to curl, the bacteria to enter the root hair cells, the cells of the root hair to divide, and then an infection thread to form and ramify in developing nodule primordia. The bacteria then undergo morphological differentiation to become bacteroids, which are ultimately freed from the infection thread to form symbiosomes thanks to the production of nitrogenase. The glutamine synthase/glutamate synthase pathway will be used by plant cells to absorb the ammonium generated in the nodules into amino acids for the plant's usage. Rhizobia provide a source of nitrogen for plant development, but legumes also offer protection and photosynthesize for the rhizobia, which they use as a carbon source.

In forest biomes, the interaction between actinorhizal plants and the actinomycete Frankia through nodule development is another frequent N2-fixation symbiosis. The capacity to create mutualisms with mycorrhizae and tripartite symbiosis gives many actinorhizal plants and shrubs an advantage to flourish in soils with low nutrient availability. The method Frankia use to infect their host plants will vary depending on the type of both the host and Frankia.

However, they are comparable to rhizobia's methods, which include hair infection, crack penetration, or epidermal invasion. Actinorhizal plants that are members of the order Rosales have Frankia enter their cells via the roots, while actinorhizal plants that are members of the order Fagales have Frankia enter their cells through the root hairs. Actinorhizal plants may fix a significant quantity of N2 in nodules that develop indefinitely and are comparable to those produced by legumes[3].

Non-Symbiotic N2 Fixation

Azotobacter and Klebsiella are only two examples of the many free-living heterotrophic diazotrophs in the rhizosphere that may fix atmospheric N2, but not in direct contact with any other species. As a result, these bacteria must find their own sources of energy to complete the very energy-intensive BNF process. They can often oxidize organic molecules produced by decomposition or with the help of other species, while some have chemolithotrophic skills that allow them to use inorganic substances as an alternative source of energy. According to reports, the amount of organic matter in the soil and the free-living BNF rates are significantly associated, with greater rates seen in woody wastes and surface organic layers than in mineral soil. These bacteria must also be able to function as anaerobes or microaerophilic during the N2 fixing since oxygen limits nitrogenase activity.

As a result of these limitations, free-living N2 fixation, as opposed to symbiotic N2 fixation, will not be able to make a significant contribution to BNF in the majority of ecosystems. It was also noted that significant quantities of N were fixed by free-living N2 fixers in rain forests.

Additionally, research has indicated that owing to N deposition, leguminous plants in mature tropical forests do not fix as much N. Other bacteria, including Azospirillum and Herbaspirillum, may connect with different kinds of plants to develop mutualisms or form endophytic relationships. Without the development of specialized structures, this method of N2 fixation is comparable to symbiotic N2 fixation in which the diazotrophs acquire reduced carbon and other nutrients from the plants while supplying fixed nitrogen for the plants to consume[4].

Support for P Acquisition

N is often thought of as the main restricting nutrient in many forest habitats, however P is also a significant restricting factor. For plants to carry out several metabolic activities including signal transduction macromolecule synthesis, respiration, and photosynthesis, phosphorus is essential as a key component of their energy supply. According to several reports, excessive N deposition that is not accompanied by an equivalent rise in P inputs may result in nutritional imbalances that ultimately slow down the development and productivity of forests. It has been shown that when plant P concentrations and N: P ratios decline, there is a rise in demand for P as growth promotion occurs after the addition of N. Additionally, there is data that indicates that P deficiency has had a negative impact on the rate of N2 fixation in tropical forests, which are mostly made up of non-leguminous tree species.The majority of soil has a lot of phosphorus, but there isn't much of it that plants can use since >90% of the phosphorus in the soil is insoluble and precipitated. Only soluble P sources, such as monobasic and dibasic HPO24 ions, are accessible to plants. Although commercial fertilizer offers enough soluble inorganic P, the majority of these nutrients are immediately immobilized after application, making them inaccessible to plants. Therefore, using microbes to assist in P solubilization and mineralization would be a sustainable option. These microorganisms may be split into two main groups: mycorrhizal fungi and phosphate solubilizing microorganisms[5].

Microorganisms That Solubilize Phosphate

PSMs have been shown to significantly improve the availability of P to plants by solubilizing and mineralizing complicated P molecules. There is a numerous method that PSMs may use to dissolve insoluble P forms, but the major one is recognized to be the secretion of organic acids of low molecular weight, such as acetic, citric, and gluconic acids. In order to acidify these microorganisms and their surroundings, the OA produced will either chelate the mineral ions or decrease the cell's pH level, causing the P-ion to be freed from P-mineral through the swap of H+ for Ca2+ instead. The kind, concentration, and quality of OAs discharged into the soil have a significant impact on how well they are solubilized, with OA quality being more important. The P Solubilization process may be further improved by the PSMs' capacity to secrete many OAs at once.Some studies have also shown that soluble forms of P may be converted to insoluble forms of P without the creation of OA. According to Altomare et al., Trichoderma harzianum strain T-22 was able to solubilize P, perhaps as a result of chelation and reduction activities, and also gave the plant biocontrol without the need for acidification.

Inorganic acids generated by chemoautotrophs have been shown to solubilize P in addition to producing OA by breaking down tricalcium phosphate into mono- and dibasic phosphates.Organic phos-phorus may be mineralized by phosphate-solubilizing microorganisms by secreting phosphatases and phytases that catalyze the hydrolysis of phosphoric esters. The primary process in the mineralization of organic P has been postulated to be acid phosphates, which are often present in fungus. P is then released from organic molecules that have been held as phytate by phytase. Despite the fact that plants often are unable to get P directly from phytate, PSMs in the rhizosphere may be able to mitigate the consequences. One PSM strain was capable of mineralization and phosphate solubilization. Azotobacter, Bacillus, Bradyrhizobium, Burkholderia, Enterobacter, Microbacterium, Paenibacillus, Erwinia, Mezorhizobium, Rhizobium, Pseudomonas, and many more bacterial genera are examples of those capable of solubilizing and mineralizing P. Aspergillus, Cladosporium, Penicillium, Rhizoctonia, Rhizopus, Sclerotium, Trichoderma, and other fungi are among the genera that produce fungal PSMs.

Mycorrhizas

Many plants may form symbiotic relationships with mycorrhizal fungus, either obligately or facultatively, in which the mycobionts depend on their hosts for photosynthetic materials and energy while providing a variety of advantages to them. One of the most often researched PGPMs utilized in bio fertilizer for forestry applications is this group of microorganisms.By spreading their mycelia from root surfaces into the soil, fungus may increase surface areas for improved access to obtain nutrients, in particular insoluble phosphorus sources. In addition, mycorrhizal fungi may enhance soil aeration and quality, lessen plant vulnerability to phytopathogens, and increase host plant tolerance to environmental stressors.

Mycorrhiza may invade the root tissues of their host plant either intracellularly or extracellularly. Consequently, they fall into one of two major categories: endomycorrhiza, and ectomycorrhiza. Arbutoid, ericoid, monotropoid, and orchid mycorrhizae are further subcategories of endomycorrhizas. Arbuscular mycorrhizal fungi, which are obligate mycobionts and may create mutualism with more than 80% of vascular plants, are the most typical mycorrhizal associations. Vesicles and arbuscules are specialized AMF structures that help with mineral and water uptake from deeper soil layers as well as mobilizing and making P accessible to their host plants. AMF biofertilizer manufacturing on a big scale is a particularly challenging operation due to AMF's obligatory nature and inability to be produced as pure cultures apart from their hosts[6].

Despite being widely dispersed across various habitats, ectomycorrhizal fungi are only connected to 3% of the vascular plant groups, especially woody trees. However, since they work well in symbiotic connection with many significant woody plants, they are vital for managing forests and ecosystems. The majority of ECMF species belong to the phylum Ascomycota, and rarely Basidiomycota. The Hartig network, which is an intercellular interface created by very branching hyphae to build a lattice between epidermal and cortical root cells, allows metabolic interaction between the fungus and the root even when ECMF are unable to penetrate the cell walls of their host plants. Minerals and water may be mobilized, absorbed, and translocated to the hosts via the thick hyphal coating, known as the mantle, generated by ECMF. This often helps the hosts survive under challenging situations.Since they may help plants get P, N, water, and other minerals in forestry, ECMF have been researched and used as bio fertilizer since the late 1950s. These fungi are more often used in nurseries, where tree seedlings are infected in the nursery before being planted in the field to guarantee a healthy fungal system.

The right choice of plant-host species is crucial for a successful ECMF connection. When combined with ECMF, mycorrhizal helper bacteria have been shown to promote mycelial growth, increase interaction and surface areas for root-mycorrhizae colonization through the production of phytohormones and flavonoids, and lessen the negative effects of environmental stress on mycelia. Potassium SolubilizationIn plants, potassium is a crucial macronutrient for protein synthesis, photosynthesis, phloem transport, and enzyme activation. Since most potassium is found in silicate minerals and insoluble rocks, soil typically contains very little potassium that is soluble. K for plants is mostly obtained from the soil, and the soil's availability of K isDependent on K dynamics and content in the biomes. Additionally, K deficiency may have a negative impact on the soil microbial population, which would lead to ineffective nutrient cycling in the forest biomes.It has been proposed that biotic variables may have a significant impact on the K dynamics and distribution in plant tissues, soils, and water in forest biomes. Stressors like as wood harvesting, forest fires, and intensification of land use might potentially have an impact on K availability.

Many forests that have had tree species regularly harvested for fuel, fertilizer, and other purposes may have witnessed a decline in the quantity of K present in the environment, which may have slowed the K availability for different tree species' growth and development. Additionally, the ecology of the forest biomes may suffer if other significant limiting nutrients are added by atmospheric deposition without increasing the quantity of K.Potassium-solubilizing bacteria that create OAs may be used to release K from a variety of insoluble minerals, such as illite, micas, and orthoclases, in order to alleviate K shortages in the soil. Through the direct solubilization of rock K or the excretion of chelated silicon, the OAs may convert K into soluble forms. These acids promote the solubilization of K compounds by supplying protons and creating complexes with soil-based metal ions like Ca2+. Arthrobacter, Acidithiobacillus, Bacillus, Burkholderia, Paenibacillus, and other genera are examples of KSM genera[7].

Siderophores are Produced

As a key component of redox enzymes that help with oxygen transport, cellular proliferation, chlorophyll production, and nucleic acid synthesis, iron is a crucial trace element for plant development. Despite being the fourth most abundant element on earth, Fe is difficult for plants and microbes to absorb since it mostly exists in nature as Fe3+ and tends to produce very insoluble oxides and hydroxides when exposed to oxygen, especially in calcareous soils. Iron has been claimed to be a limiting element in certain mangrove forests, despite the fact that it is not a limiting factor in many forest biomes.

Microorganisms may get Fe in Fe-limited environments by secreting siderophores, which are low-molecular mass iron chelators with a strong affinity for Fe3+ ions. When siderophores attach to Fe3+ ions, they create complexes that are subsequently returned to the cytosol, where Fe3+ is reduced and then secreted.

Bio-fertilizers

Through a gating mechanism, Fe2+ enters the cell and makes Fe available to the bacterium. Based on their functional groups, siderophores are grouped into three main families: catecholates, carboxylates, and hydroxamates. Out of the more than 500 known siderophores, 270 different varieties have so far been structurally described. Generally speaking, plants use one of two methods to store iron: either lowering pH levels in the rhizosphere, followed by the reduction of Fe3+ ions by ferric-chelate reductase, allowing the root cells to progressively take up Fe2+; or secreting phytosiderophores for iron solubilization, binding, and subsequent transport into root cells. However, these methods fall short in providing enough Fe for the plants in Fe-deficient environments, particularly in calcareous and alkaline soils. Assimilation of Fe from microbes would thus be a preferable choice.

Plants may absorb Fe from these bacterial or fungal siderophores through two different methods: direct Fe chelation followed by ligand exchange interaction with phytosiderophores to liberate Fe2+, or transfer of their Fesiderophore complexes to plant roots for Fe reduction to occur. Although the siderophores' primary job is to scavenge for Fe, they may also create complexes with other metals found in the rhizosphere, which enables the bacteria to use them. In turn, this could lessen the abiotic stress that hazardous concentrations of heavy metals in the soil have on plants. Along with directly enhancing plant development, siderophore synthesis also has the potential to boost plant growth indirectly by preventing the proliferation of phytopathogens by binding to the majority of Fe3+ in the root zone. The siderophores generated by PGPMs have a stronger affinity for Fe3+ than do fungal pathogens, out-competing them for available Fe, leading to the proposal that this is an efficient biocontrol mechanism [8].

Changes to Phytohormones

Phytohormones are organic compounds that, in little amounts, have the power to stimulate, obstruct, or alter a plant's developmental processes, notably in how it responds to its surroundings. Plants often attempt to control the levels of endogenous plant hormones when subjected to environmental challenges in order to lessen the negative consequences that these stresses might cause. Certain PGPMs may produce phytohormones in vitro and can adjust phytohormone levels to achieve balance, helping to control how plants react to environmental challenges. Abscisic acid, cytokinin, IAA, and GA are examples of common phytohormones that are generated by PGPMs. IAA performs a variety of tasks, including promoting cell division and differentiation, improving seed germination rates and percentages, starting and accelerating the growth of roots, controlling how plants react to stress, producing metabolites, and adversely affecting photosynthesis. Many PGPMs are reportedly capable of slowly and continuously releasing IAA as secondary metabolites, modifying the auxin pool and impacting the physiological processes of the plants. It is possible for L-tryptophan-dependent or independent pathways to be involved in the production of IAA by PGPMs. The primary precursor for the synthesis of IAA is the amino acid tryptophan, which is found in the root areas of plants. Additionally, tryptophan may boost IAA production indirectly by preventing the synthesis of anthranilate, a precursor that prevents the biosynthesis of IAA, via the negative feedback control of anthranilate synthase levels.

The most prevalent IAA biosynthesis route used by PGPMs is the indole-3-pyruvic acid pathway, which is followed by the indole-3-acetamide pathway. Diterpenoid phytohormones called GAs are essential for a variety of processes, such as stem lengthening, leaf expansion, seed germination, floral induction, breaking of dormancy in seeds and tubers, and an increase in fruit size and quantity. The three most prevalent forms of GAs that encourage plant growth and shoot elongation are GA1, GA3, and GA4. GAs are often generated endogenously by plants to control plant growth and development. The three regulatory mechanisms that govern the production of GA are catabolism, reversible conjugation, and biosynthesis. By promoting root initiation, inhibiting root elongation, quickening fruit ripening, minimizing wilting, enhancing seed germination, and inducing the production of other phytohormones, ethylene may have an impact on plant development.

Plants will release ethylene at greater quantities to combat stressors when they are exposed to them. The synthesis of ethylene requires the essential precursor 1-aminocyclopropane-1-carboxylic acid. Both endogenous and bacterial IAA have the ability to stimulate the synthesis of ACC. High ethylene concentrations, however, may result in defoliation and change cellular functions, which ultimately slow down plant development. The deleterious effects of high ethylene concentrations on plant development may be mitigated by the synthesis of ACC deaminase by PGPMs. Through the use of ACC deaminase, the beneficial microorganisms may hydrolyze ACC into -ketobutyrate and NH3, which are subsequently used as carbon and nitrogen sources, respectively, to lower the ethylene levels.

Phytoprotection

Pesticides are mostly utilized in forest nurseries and planted forests because they are the most economical way to control insect pests, diseases, and weeds, even though they are used far less often in forestry than in agriculture. On the other hand, frequent pesticide use may harm the ecology in forest biomes. Therefore, using PGPMs as biocontrol agents in forests may be a more environmentally friendly way to control pests. The biocontrol activities include the generation of hydrogen cyanide, lytic enzymes, and induced systemic resistance as well as antibiosis nutritional competition. Antibio-sis is one of the most efficient biocontrol methods used by PGPMs to stop the spread of phytopathogens. 2, 4-diacetylphloroglucinol, ecomycins, pyrrol-nitrin, pyoluteorin, oomycin A, amphisin, phenazine, and others are some of the antimicrobial substances found as being responsible for phytopathogen suppression. However, an excessive reliance on these antibiotics can cause phytopathogens to become resistant to them. To deal with this, it is preferable to use strains that can synthesize HCN in addition to creating many antimicrobial compounds[9].

Despite playing no part in their development or main metabolism, producers may benefit selectively from the creation of HCN, a volatile secondary metabolite with a low molecular weight. The pathogens' ability to synthesize certain metalloenzymes and cytochrome-c oxidase may be inhibited by the production of HCN, which would interfere with cell energy supply and hinder electron transport. However, HCN use alone does not result in considerable biocontrol action; rather, it collaborates with antimicrobial substances created during antibiosis. Additionally, it was claimed that HCN might facilitate the uptake of nutrients by chelating metal ions and increasing the availability of nutrients to the plants.

PGPMs may also use the capacity to produce lytic enzymes to directly kill fungal infections by impairing the structural integrity of their cell walls. These enzymes include -glucanase, chitinase, dehydrogenase, phosphatises, and proteases. Fungal cell walls, which are typically composed of 1, 4-N-acetylglucosamine and chitin, may be broken down by the enzymes -glucanase and chitinase. In addition to producing lytic enzymes, PGPMs might compete with phytopathogens to prevent their development by swiftly colonizing plant surfaces and consuming a large number of readily available nutrients. Additionally, owing to the shortage of iron in the rhizosphere, as was indicated in the previous section, the siderophore synthesis by PGPMs may also limit the growth of these pathogens. Plants' intrinsic defense mechanisms against future biotic stressors may be activated by PGPMs with biocontrol ability by improving their capacity to protect against certain harmful environmental stimuli. Jasmonate and ethylene signaling in plants play a role in this resistance since both hormones may enhance the host plant's defenses against infections. In addition to these hormones, cyclic lipopeptides, flagella, lipopolysacharrides, homoserine lactones, and other bacterial components have all been linked to ISR. According to reports, plants with ISR are said to react to pathogen assaults more quickly and forcefully. ISR is very successful in reducing a variety of pathogenic illnesses because it does not specifically target microorganisms.

DISCUSSION

Factors Affecting the Results of Applications of Biofertilizers Related to Forestry

The substrate known as the rhizosphere, which extends a few millimeters below the soil surface, is helpful for interactions between bacteria, fungus, and other microfauna. When the overall root length and density of a plant are taken into account, these interactions have a significant impact on the chemistry and physiology of the surrounding soil, having a significant impact on plant health and nutrition. As well as interacting with the host plant, microbes in the rhizosphere have been seen to interact with one another and within species. This is the case, for example, when N2 fixers like Azotobacter and Azospirillum or phosphorus-solubilizing bacteria work together with vesicular arbuscular mycorrhizae. Three functional fungal groups—bio-fertilizers, biocontrol agents, and bioremediators appear to be the processes by which rhizospheric fungi benefit different plant species. Longer roots and a decrease in symptoms after pathogen-induced stress are two benefits of using fungi that exhibit ACC deaminase activity to stimulate plant development.

As shown in the use of Azospirillum, the effectiveness of any bio fertilizer use in forestry generally relies on the microbial strain, inoculum manufacturing, including formulations, and field-testing tactics. In terms of germination and yield, it was discovered that plants infected with PGPR strains derived from the plants' natural rhizosphere perform better. The workability and adaptability of the microbial strains at various temperatures are significant factors to take into account; for example, a cold climate-targeted PSB should be physiologically active to solubilize P at subfreezing temperatures. This characteristic made P accessible to the evergreen pine trees throughout the harsh winter months. On the other hand, the psychrotolerant PSB species provide excellent candidates for P bio fertilizer under all conditions due to their functioning at ambient temperatures[10].The species of the host plant directly affects the parameters involved in microbial inoculation. Variations in the species, phenology, changes in the rhizosphere caused by the host, mycorrhizal dependence, as well as various unidentified host plant characteristics are known to affect AMF colonization and spore densities in the host plant. As shown in the rhizosphere of C. setosum, the host species is most important in this respect. AMF distribution in salt marshes is primarily influenced by the host rather than environmental pressures, according to Carvalho et al. The host species may also have an impact on the depth of AMF colonization. For example, Taxus chinensis and Pyrus communis rhizospheres were found to have spores at a depth of 40 cm in the subsoil, which was ascribed to the plants' deeply penetrating roots. During the monsoon season, when terrigenous sediments deposition on the mangrove soil occurs, regions showing Rhizophora growth had the highest total nitrogen concentration, according to research on the Pichavaram mangrove in south-eastern India.

A bio fertilizer testing experiment's result is also strongly influenced by the soil's characteristics. Because soil is variable, it may provide challenges as a natural habitat. According to research, the efficiency of a PGPR depends on the kind of soil used for cultivation. Plants grown on less fertile soils gain the most from the application of PGPR in terms of plant development. Low soil pH, rainfall, high temperatures, and Verticillium soil infection, according to Frommel et al., all contributed to the poor PGPR root colonization. Because of the presence of various species of fungi and bacteria, the clay soil on the edges of the Pichavaram mangrove forest is rich in calcium, magnesium, nitrogen, and phosphorous as well as producing hydrogen sulfide. These organisms also help with nitrogen fixation and phosphate availability. The amount of soil moisture should also be taken into account since it may have an impact on how well plants develop after vaccination. High moisture content, however, may cause a decrease in soil oxygen levels, therefore this element relies on the kind of PGPR.

The region that a certain microorganism is obtained from has an impact on the bio fertilizer’s efficacy as well. The most important groups of PGPRs, obtained from the ectorhizospheric zone and among endosymbionts, involve phosphate-solubilizing species such as Acinetobacter, Serratia, Arthrobacter, Aspergillus, Burkholderia, Alcaligenes, Erwinia, Azospirillum, Pseudomonas, Bacillus, Enterobacter, Flavobacterium, Penicillium, and Rhizobium. AMF are present in a variety of habitats, including stress-inducing settings like acid-saline and saline soils. According to research, the AMF dispersion is influenced by the physiological traits of the host and the morphology of the roots. Regarding the discovery and impacts of Bio-fertilizers on specific tree species, mangrove forests have drawn a lot of interest. Three species of the nitrogen-fixing Azotobacter, A. vinelandi, A. chroococcum, and A. beijerinckii, have been found as possible biofertilizers in mangrove nurseries and prawn ponds. Mangrove environments are known for housing colonies of these bacteria.

The concept of a "mangrove vegetation trap" for seafood harvesting was developed based on the conditions above. The high levels of nitrogen caused by leaf decomposition and the presence of the listed microbes are known to attract amphipods, crabs, fishes, isopods, prawns, and young oysters. Additionally prominently present in mangrove regions are cyanobacteria. In the Pichavaram mangrove region of India, 15% of the phytoplankton population is made up of aerial N2-fixing cyanobacteria, which grow abundantly on the lower and middle sections of the aerial roots throughout the summer and post-monsoon seasons. Phormidium species have a reputation for tolerating salinity and have a lot of promise as Bio-fertilizers and formulations for shrimp feed[11].

Combinations of microorganisms may also provide better outcomes in field studies employing bio-fertilizers than using isolated fungi or bacteria. It was shown that using a microbial mixture rather than a single isolate may increase a plant's ability to solubilize phosphate. There are several explanations for this phenomenon, including improved growth conditions for other isolates due to one isolate's metabolic products, the contribution of P-solubilizing functions by other isolates when one isolate can no longer dissolve phosphate due to changes in the culture conditions, and the diversity of microbes involved in the process. The movement and reproduction of nematodes in Pinus pinaster and P. pinea were found to be restricted by a bio fertilizer enriched with N-providing free-living diazotrophic bacteria and Cunninghamella elegans, a chitosan-producing fungus, as well as the mitigation of infection symptoms in the former. Phosphate-solubilizing microbes are also known to have the ability to exert biocontrol; this ability is demonstrated by a difference in the colonization of AMF inside and outside of plant roots, as well as other growth parameters for the host plant, demonstrating its effectiveness on both the target plant species and the local microbial community.

The successful transfer of laboratory-based experiments to the field, which has been demonstrated in some research to be not feasible despite the fulfillment of all the conditions given above, is a significant obstacle in any study employing Bio-fertilizers. The mismatch in interactions between the soil biota and the bio fertilizer is blamed for this phenomenon. Therefore, it's critical to guarantee that the ecological traits of every component of a bio fertilizer are well-characterized, as well as their interactions with the microbiota. The PSM isolates, particularly Trichoderma paratroviride PWF-1 and Bacillus megaterium PWB-4, did not exhibit antagonistic behavior toward one another or other P-solubilizing fungi, according to Hayat et al. This suggests that they could be established as bacterial or fungal-bacterial combinations to increase soil P availability. The difficulty in carrying out such studies may also be related to the influence of climate, which is known to have a significant impact on the efficacy of an applied PGPR and, therefore, the results of a field experiment.

Forestry Applications of Bio-fertilizers

As was indicated in the preceding section, attempts to transfer forestry-related bio fertilizer trials from the lab and greenhouse to the field have had little success. Success is restricted to tree species that can be found in certain places across the world. Mallik and Williams and Lucy et al. both provided summaries of certain studies that used PGPR in different forest tree species. Only a small portion of the study was carried out in the field; the majority was done in the growth chamber and greenhouse. However, field tests showed that different pine, beech, oak, and spruce species inoculated or co-inoculated with Arthrobacter sp., Pseudomonas sp., Bacillus sp., Azotobacter sp., and unidentified bacterial strains or AMF had increased biomass, shoot and root growth, nutrient uptake, foliar nitrogen content, pathogenic biocontrol, and seedling emergence. When seedlings were inoculated, it was discovered that mangrove forests, which are known to be deficient in soluble nutrients, particularly phosphorus, fared better. With cyanobacteria, phosphobacteria, Azotobacter, and Azospirillum.

When the experiment sites' rhizospheres were injected with bio-fertilizers derived from habitats native to both the tree and microbial species, greater success was shown. Any bio fertilizer experiment's performance is influenced by climatic factors, which might vary from those in a lab or greenhouse. Extremely cold environments, such as tundra ecosystems, present a challenge for microbial interactions, and as a result, psychrophile or psychrotolerant bacteria are dominant there. These bacteria can withstand the cold by producing cold-shock proteins, enzymes, genetic changes from thermal shifts, and short unsaturated membranous acids, among other things. Based on this rationale, Hayat and his colleagues isolated PSB in the Himalayan area in order to measure the ecological traits of the isolates, as well as their capacity to transform inorganic phosphorus into accessible phosphorus and interact with microbiota present in the rhizosphere of Pinus species. The researchers found that 31% and 69% of PSB had both common and unique P-solubilizing characteristics. 48 percent of the latter were labeled as "efficient P-solubilizers." Eleven and four, respectively, of the 16 efficient PSBs that were isolated were found in the lower subsurface and surface of the Himalayas. Ochrobactrum anthropic, which was isolated from the pine rhizospheric subsoil, has the greatest level of P-solubilization.

Eight PSB were tested, and four were shown to be resistant to nematode grazing; the other three and one PSB were, respectively, resistant to nematode grazing for 96 and 120 hours of co-culture. The research emphasized the significance of isolating local microorganisms from the region where the tree species is present in order to boost the target microorganism's capacity for fertilization. Microorganisms targeted as Bio-fertilizers must be carefully chosen based on their traits in order to boost the effectiveness of efforts to improve plant growth and development or soil cleanup. Plant development activities and increased tolerance to high pH and salinity levels were both shown to benefit from AMF. When compared to any concentration of plant-available P in the soil, it was shown that AMF inoculation offered the plants more effective protection against salt stress. Glomus mosseae and G. caledonium are salt-tolerant AMF species that call for further research into their functions in plants.

They are mostly found in the alkaline and saline soils of the Yellow River Delta. Contrarily, Trichoderma specie, a common fungus specie, is known to enrich soil via nutrient solubilization, particularly in sterile or pathogen-infected substrates, which may result in increased plant yields and improved plant resilience to pathogenic stress and drought. Trichoderma causes bound nutrients in the soil to release and become soluble. When seedlings were infected with Trichoderma from mangroves, it was revealed that both the biomass and the tested biochemical parameters increased by 70% in Rhizophora apiculata and R. mucronata. Once again, the results clearly suggested the possibility of employing Bio-fertilizers obtained from regions where the target plant is native. Bio stimulants are sometimes made by combining certain substances or chemicals with microbes. Regardless of the nutritional circumstances, a chemical is deemed to be a bio stimulant if it is shown to improve or affect a plant's quality, nutritional status, or reaction to stress. There are now five kinds of commercial bio stimulant products: amino acids, fulvic acids, microbial inoculants, humic acids, and seaweed extracts.

The eucalyptus hybrid E. grandis x E. urophylla was found to benefit from the use of a bio stimulant when applied in both solid and liquid forms, with increased root length and mass being seen, especially in the case of the former. The bio stimulant was reinforced with A. flavipes cultured in soybean bran and with various amounts of IAA. Similar outcomes have been observed for other Aspergillus species. In Solanum tuberosum and Arabidopsis thaliana, it was discovered that A. ustus encouraged shoot and root development as well as an increase in lateral root and root hair counts. By inoculating Cicer arietinum shoots and roots with both

Aspergillus niger and Trichoderma harzianum, similar results were seen. The natural substances included in Bio-fertilizers improve the nutritional state and natural resilience of plants. Microbial inoculations may promote adventitious root formation, particularly in species that have trouble establishing roots, which raises host-plant biomass, nutrition and water uptake, and stress tolerance levels. Even in the absence of data, it is clear that Bio-fertilizers have a significant impact on agricultural yield and also hold enormous promise for cleaning up forests and the environment. However, there is currently a dearth of study in the subject of forest Bio-fertilizers. For deciduous trees, no field data have ever been gathered, while few coniferous species have had any field data recorded. As a result, additional study in this area may provide a wealth of information that will help us comprehend the many biotic interactions that take place in all forests. The bulk of trials conducted in labs and greenhouses have not been effectively translated to the outdoors. The rhizosphere is a complex ecosystem that must be taken into account in any research on bio fertilizer. Research on the rhizosphere's structure and function has run into difficulties, particularly when trying to understand the molecular processes that underlie all biotic interactions and communications within the substrate. However, the employment of contemporary analytical technologies, such as functional genomics, direct soil DNA extraction and amplification followed by community fingerprinting, reporter gene technology, confocal microscopy, and stable isotope profiling, is now facilitating this process. Recent research is also focusing on determining how these interactions affect above-ground communities as a result of an ecosystem-based feedback loop. It is also possible to label inoculants with the lux or gfp genes to make them simpler to find and count in the field.

For this, it is important to study indigenous populations' traditional and ethnobotanical knowledge. The interactions between the microbial fauna present in the rhizosphere may lead to the synthesis of active chemicals, which may be shown by phytochemical and pharmacological investigations of medicinally significant forest plant species. On the basis of the phytochemistry, pharmacognosy, and pharmacology of the plant species, new medicinal medicines may then be created. As some study has shown, inadequate elimination of plant diseases like nematodes or merely a decrease in inocula sizes after application of the bio fertilizer are necessary for factors linked to the administration of Bio-fertilizers for maximum production. However, other investigations have shown the existence of nematode grazing isolates that are pathogen resistant, demonstrating their capacity to feed crucial components under pathogenic assault and so protect target plants from diseases. We may investigate characteristics like these to learn more about how a bio fertilizer functions. With careful matching of a bio fertilizer with the host plant species to the surrounding environment, which is beneficial in that a natural or intentionally manufactured microbe may be employed for this purpose, positive impacts on plant developmental activities can be noticed.

CONCLUSION

Bio-fertilizers are becoming more and more important in both horticulture and agriculture as viable alternatives to pesticides for promoting plant development. The intricacy of the rhizosphere and the interactions between all of its residents are addressed through cross-disciplinary research encompassing the disciplines of microorganisms, soil, plants, ecology, physiology, molecular biology, chemistry, and physics. The existence of potentially effective Bio-fertilizers has not been investigated in vast regions. As a result, efforts should be undertaken to record the performance of microorganisms or plants in undiscovered or underexplored regions worldwide. Future studies in this field can especially profit from research involving synergism and environmental persistence in all components of a bio fertilizer to promote plant development, particularly on the development of an efficient and effective novel bio fertilizer delivery systems catering to the traits of the plant and microbial species involved. The results of this study may then be utilized to support in situ reforestation efforts by using Bio-fertilizers. Future bio fertilizer production tactics may also benefit from year-round management and application techniques that are economical, scalable, long-lasting, and unaffected by environmental or climatic factors. To ascertain their efficacy, more field research including commercial Bio-fertilizers and delivery systems are needed. By using agro-industrial waste, sustainable techniques of creating Bio-fertilizers may be started. The establishment of efficient Bio-fertilizers for sustainable forestry ultimately depends on aspects including efficient strains, bulb production, host compatibility, proper formulations, economic viability, and technological transfer capabilities.

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CHAPTER 2

IMPACT OF BIO-FERTILIZERS ON HORTICULTURAL CROPS

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ABSTRACT:

The ever-increasing global population, climate change, as well as pest and disease outbreak remain as challenges to the horticultural crop production. There is an urgent need to intensify crop production using sustainable methods. Plants are associated with rhizosphere microbes, which have the ability to promote crop growth and stress tolerance, enhance plant nutrition, and improve vegetation propagation. Thus, the formulation and application of Biofertilizer containing these beneficial microbes is a promising approach to improve horticultural crops. In this chapter, the impact of applying Biofertilizer will be discussed comprehensively which will include the possible mechanisms of Biofertilizer in conferring plant growth promoting and stress tolerance traits in crops. This chapter will also look at the possible challenges that will arise from Biofertilizer application and recommend solutions to ensure the most efficient use of Biofertilizer in the horticulture industry.

KEYWORDS:

Abiotic Stress, Biofertilizer, Biotic Stress, Crop Tolerance, Horticulture, Yield.

INTRODUCTION

With low- and middle-income nations starting to change their dietary habits in order to consume more vegetables and fruits due to improved buying power, the horticulture business is one of the fastest expanding sectors to meet the rising demand. Additionally, the projected global population for 2025 is around 8.5 109, which implies a sizable quantity of agricultural product is required. Such high demand frequently necessitates the heavy use of chemical fertilizers and pesticides to increase yield, but these methods have also been linked to soil pollution, infertility, eutrophication of water sources, pesticide-resistant insects and plant pathogens, compromised food safety and quality, and consumer health risks. The need for nitrogenous fertilizer is estimated to surpass 130 million tons annually, and the dependence on these resources not only harms the environment but is also unfeasible economically since the creation of synthetic N fertilizer is highly dependent on the usage of fossil fuels. The use of microbial-based fertilizers, also known as Biofertilizer, is an option that, in addition to being user- and environmentally-friendly, provides ongoing food production under changing environmental circumstances, which is the objective of sustainable horticultural farming[1].

A designed product containing one or a combination of microorganisms is referred to as a Biofertilizer because it may increase nutritional content, growth, and yield by making nutrients accessible to plants. To increase microbial viability in varying circumstances and to make sure their effectiveness won't be diminished when subjected to biotic and abiotic challenges, these beneficial microorganisms are often created into dry and liquid formulations. Commonly utilized beneficial bacteria come from natural sources including the plant's nutrient-rich rhizosphere and phyllo sphere, which are home to mycorrhizae fungi and microbes that promote plant development. The capacity of these bacteria to fix nitrogen, solubilize phosphate and potassium, create plant growth regulators, and biodegrade organic soil debris are often what define their PGP qualities, which lead to improved crop development and production. In general, only 10% to 40% of applied chemical fertilizer is absorbed by plants, while more than 60% to 90% of it is lost via soil leaching. In order to assure nutrient usage efficiency and to increase nutrient availability for crop development and production, the use of Biofertilizer has a tremendous potential in integrated nutrient management. Biofertilizers were discovered to alleviate biotic and abiotic stressors in crops in addition to increasing crop output. Crop production has been significantly affected by abiotic variables such as drought, floods, rising temperatures, and soil salinity due to climate change. Similar to this, one of the main causes of crop loss is biotic stress, which includes the invasion of weeds, nematodes, insect pests, and plant infections. Additionally, certain helpful microorganisms may both increase crops' tolerance to biotic and abiotic challenges and foster crop growth and production when stressed.

The importance of Biofertilizer in promoting growth and yield, increasing tolerance to biotic and abiotic stress, and facilitating vegetative propagation of horticultural crops will be highlighted in this chapter. This chapter will also discuss potential solutions to these obstacles as well as upcoming issues with the use of Biofertilizer that horticulturists and researchers should be aware of. Microorganisms Applied to Biofertilizers Given the significant negative impacts of using chemical fertilizers and pesticides, employing Biofertilizer is an option to lessen these substances' negative effects on crop productivity, the environment, and people. Through their interactions with the inoculated hosts, various microbial strains were incorporated into formulations that could improve plant nutrient uptake and increase plant tolerance to biotic and abiotic stresses. This was accomplished by harnessing the microbial diversity in the plant root rhizosphere region. Key bacteria strains that are often utilized in the creation of Biofertilizer[2].

Effect of Applying Biofertilizer on Horticultural Crops

Enhanced Crop Yield and Quality

The increase in crop production and quality is one of the evident effects of using Biofertilizer on horticultural crops. The root rhizosphere is where the overall increased crop growth performance starts. The intricate relationship between microbial inoculants and the rhizosphere zone influences how well a plant can generally absorb nutrients. The majority of the carbon that beneficial bacteria get from plants comes through their root exudates, and in return, they make nutrients accessible for plants to absorb.

DISCUSSION

The seed output of climbing beans was increased by 89% and 30% when native Rhizobium isolates were used instead of commercial Rhizobia-based Biofertilizer. Native strains may interact harmoniously with other local microbial communities because they have been adapted to the local agro-climatic conditions, which leads to increased soil health, nutrient availability, and higher yields. Different agroecosystems in the same research displayed varying seed yields, with lower midland systems producing 4,691.26 kg/ha more seeds than higher midland systems, which suggests that different soil qualities and nutrient levels may have an impact on rhizobial nodulation. For instance, despite the high concentration of native rhizobia strains, P deficient soil impacts the biological nitrogen fixation activity, and replenishing the soil with P aids in enhancing BNF activity in plant roots. Rhizobia Biofertilizer application also increased the seed output of Faba and runner beans. Rhizobia's potential role in increasing legume seed production has been hypothesized. The discovery of

GFP-tagged Azospirillum brasilense in developing seeds proved that Rhizobia strains actively move and build an intercellular colonization in the developing seeds as addition to colonizing roots. The quantity of beans in pods and the size of the pods could have been affected by this colonization activity. Therefore, further research is required to understand how bacterial seed colonization could increase seed output in leguminous plants. The seed output of cowpea was unexpectedly lower when compared to exogenous application of novel strains of Brady rhizobia in an agricultural area rich in native Brady rhizobia. Possibility analysis

Biofertilizers Regarding Horticultural Crops

Also shown that inoculated plants had higher net returns than the inoculated control, $104–163/ha. Due to competition for nutrients and space, a high native Rhizobia population in the soil naturally reduces the efficacy of imported strains, however this was not the case in our investigation. Rhizobia may not be as successful as expected because native strains, as opposed to foreign strains, have poor colonization patterns under adverse soil chemical characteristics. Under both N-deficient and supplemented circumstances, the application of Brady rhizobium's peat-based formulation increased the seed output of other legumes like soybean and mung bean. It was also shown that other environmental conditions, such as the kind of soil and the quantity of rain, have an effect on the colonization behavior of helpful bacteria. In contrast to sandy loam soil, which only exhibited improvement in yield from 7.6 to 14.9 t/ha during the brief rain season, the application of commercial Rhizotech Biofertilizer boosted sweet potato tuber yields from 12.8 to 20.1 t/ha in sandy clay soil.

Due to expanded fungal hyphae on the rhizosphere, the colonization of AMF was also shown to be greater during short rain seasons, boosting nutrient availability for plant development.Future research should include environmental variables and strategies to improve the poor colonization behavior in the rhizosphere area in order to exert the beneficial impacts of Biofertilizer on the production of horticulture crops. After applying Biofertilizer to several vegetable crops, yields increased while excessive fertilizer consumption was also decreased. The use of Trichoderma-based fertilizers increased the production of tomato and mustard by 203% and 108%, respectively, while using 50% less nitrogen fertilizer. Similar to this, the application of a consortium of Bacillus and Pantoea produced excellent cauliflowers, decreased the use of chemical fertilizers by 25%, and delayed the initiation and maturity of curd by up to 20 days. The use of Biofertilizer not only decreased the reliance on chemical fertilizers but also improved the yield quality in vegetable crops like broccoli and tomato. The macro- and micronutrient content of the broccoli was increased by using individual inoculants of Bacillus, Brevibacillus, and Rhizobium.

The commercial Biofertilizer Baikal EM1, which contains a combination of Lactobacillus, Phodopseudomonas, and Saccharomyces, increased tomato plant yield by 19%–21% through soil application and by 13%–14% through foliar application, as well as fruit biomass by 14.30 g per fruit. Additionally, Cabrini et al. found that lettuce infected with Torulaspora globosa, a rhizospheric yeast, provided improved yield quality in terms of leaf size and quantity. On the other hand, while these strains increased the biomass of seedlings, the inoculation of Bacillus and Pseudomonas did not enhance the quality and productivity of lettuce when transplanted to the field. Such discrepancy may be caused by these strains' incapacity to survive in hostile field conditions. Another instance shows that, despite the inoculation of Bacillus amyloquefaciens considerably increasing output, uneven size of broccoli was discovered. Given that crop uniformity has a significant impact on customer preferences, even if yield increases, the overall quality of the product should be standardized. According to Gange and Gad, the inconsistent microbial colonization behavior in plants as a consequence of incompatibility with native strains has resulted in different sizes of broccoli. Future commercial PGPR solutions should be designed to work with certain crops and soil types in order to produce crops with consistent yield and quality.

Fruit Crops

The impact of using Biofertilizer on the productivity and quality of strawberry crops has received a lot of research. As treated with Pedobacter and Bacillus strains, straw-berry plant crop maturity days were shortened to around 2 weeks as compared to the uninoculated control. PEDOBECURUS SPR. By particularly raising the fruit length and form index by 28% and 36%, respectively, strawberry quality was enhanced. Using Azospirillum and commercially available microorganisms increased strawberry fruit weight on average by 14.3% while having no discernible impact on fruit quantity. Compared to other micro-bial treatments, the berries generated by the Azospirillum treatment had a vivid red hue. No matter how the biofertilizer was applied, the infected plants' overall sweetness index increased and their total titratable acidity significantly decreased. The induction of strawberry flowers was raised by 35% when P. fluorescens strain Pf4 was combined with AMFs from the genera of Septoglomus, Funneliformis, and Rhizophagus. This resulted in an increase in the amount of fruit by 22% and an increase in fruit weight per plant by 14% to 20%. However, when the AMFs were combined with Pseudomonas, the total fresh fruit weight was lowered by up to 17%, and there were much fewer blooms. Strain incompatibility has jeopardized the capacity of AMF to colonize strawberry plants, which has therefore had a severe impact on the general physiology of the strawberry plants. In a related investigation, commercial items Rhizocell C containing B were inoculated. Amyloliquefaciens increased strawberry plants' ability to photosynthesize, increasing their fruit output and biomass.

Compared to other commercially available products like MYC 800 and Mykoflor, in two seasons of planting. In order to increase strawberry productivity and quality, using Biofertilizer with suitable microbial strains is crucial. After using Biofertilizer, mango production, quality, and shelf life were all improved. In comparison to the control, the application of Azotobacter and a half dose of inorganic fertilizer boosted yield and average fruit weight. The mango fruit now has a 10-day shelf life instead of only 5-days. This finding was also consistent with other studies that used a combination of AMF and PGPR strains in comparison to the wintertime. The population of the imported strains may have changed as a result of seasonal fluctuation, such as the cold winter temperatures, which might have affected the production.

Higher levels of photosynthates, such as starch and carbohydrates, which are subsequently used as energy to generate flowers and fruits, are connected with improved plant development. Additionally, the photosynthates will be transferred to the fruits at this time, enhancing postharvest quality. After the application of a combination of Azotobacter, Azospirillum, and versicular-arbuscular mycorrhiza, the average quantity of papaya fruits per tree rose to 19.72. Higher total soluble sugar, more beta-carotene, and lower acidity all contributed to an overall improvement in postharvest quality. Pomegranate fruit output steadily increased from 18 kg per plant to 38 kg per plant over the course of five years after consistent application of AMF and Azotobacter. The improved vegetative growth characteristics, such as plant height and plant canopy, were shown to be connected with the tree's production.An additional transcriptome analysis showed that bananas inoculated with rhizobacteria like Pseudomonas and Bacillus displayed differential expression of genes that were associated with growth promotion and regulation of specific functions like flowering, photosynthesis, glucose catabolism, root growth, and plant defense genes against biotic and abiotic stress. Therefore, even having a serious disease infestation, banana trees may still generate a harvest.

Garden Decorations

The floriculture sector was shown to have significantly benefited from the use of AMF Biofertilizer. Typically, AMF inoculation led to more blooms, more blooming plants, or early blossoming in ornamental plants. AMF, however, has also been implicated in flowering start delay and flower count reduction. The competition between AMF and flowers for nutrients and photosynthates, the preference of AMF in colonizing host plants, and the capacity of AMF to overcome nutritional deprivation or other types of environmental stress are all possible explanations for the different responses of host plants to AMF. Therefore, the fertilizer regime, soil fertility, and the species or cultivars being produced all have a significant impact on the utilization of AMF in the floriculture business. Petunia, geranium, carnation, gladiolus, chrysanthemum, dahlia, and poinsettia are just a few of the ornamental plants whose overall growth and flowering characteristics have been said to be improved by Biofertilizer containing PGPR, phosphate solubilizing, and nitrogen fixing bacteria. When NPK fertilizers were employed in conjunction with phosphate solubilizing and nitro-gen fixing bacteria, important flowering traits including the start of blooming were dramatically shortened in petunia by up to 20 days. After treating prize flowers with AMF or Pseudomonas, Saini et al. also had results in shortening the flowering period and expanding the size of the flower head. When Azotobacter or phosphate solubilizing bacteria were used, the vase-life of the gladiolus floral spike was extended from 11 to 16 days while the overall number of florets doubled from 8 to 16 in size. These blooming properties are crucial for producing long-lasting blooms that will satisfy market expectations. The application of Azotobacter did, however, expedite the withering of the basal florets, albeit the exact mechanism is yet unknown. Similar to this, poinsettia treated with P. putida had decreased anthocyanin concentration, which may have an impact on the bracts' colour. These findings may reflect inadequate microbial colonization brought on by the generation of Regarding Horticultural Crops, Biofertilizers [3]. Host’s antimicrobial metabolites as a kind of protection. Therefore, further research is required to better understand how these helpful microorganisms colonize ornamental plants. Future studies may also focus on using Biofertilizer to create attractive plants with increased petal or bract hues and bigger blooms that respond to customer demands. The economic viability of employing Biofertilizer in the floriculture sector should also be emphasized in further study so that industry participants may use this environmentally friendly technology to lower fertilization costs and meet customer needs.

Improved Produce Nutritional Value

The nutritional value of crops might be increased by bio fortification employing Biofertilizer, in addition to increasing crop output and quality. Other bio fortification techniques, including breeding or transgenic technologies, take time, need technical expertise, and may be subject to different government regulations before being put into use for commercial purposes. In general, a variety of mechanisms may be used to accomplish microbial bio fortification of crops.

Bio fortified Crops with Minerals

By excreting tiny molecules or organic acids, some microorganisms are able to solubilize minerals or micronutrients like iron and zinc. Rhizobia strains are attracted by the buildup of root phenolics in soils lacking in Fe, which helps leguminous plants nodulate.

Under Fe-deficient conditions, these strains generated siderophores to solubilize Fe, which subsequently encouraged the binding of Fe to host plant-derived transporter proteins. The assessment of Fe concentration in the vegetative sections of legumes and tomatoes, rather than the beans or fruit that people eat, has been the focus of the majority of investigations too far. In reality, HarvestPlus generated the only effective Phaseolus vulgaris beans with iron bio fortification by selected breeding, not microbial bio fortification. Compared to control treatment and traditional NPK fertilization, tomato plants treated with Trichoderma Biofertilizer had higher Fe content in their fruits. Further study on the use of Biofertilizer in producing iron-bio fortified horticulture crops is required since iron deficiency is still a problem and is the main cause of anemia sickness. On the other side, it has been shown that slightly acidic soil increases Zn bioavailability to plants, hence Zn solubilization may be accomplished when bacteria or AMF produce organic acids to reduce soil ph. Agrobacterium Ca-18, Azospirillum lipoferum, and Pseudomonas sp. are bacterial strains that produce chelating substances like ethylenediamine-tetraacetic acid. Was able to improve the bioavailability of zinc to plants by chelating Zn ions. According to a number of investigations, inoculating liquid formulation with Pseudomonas sp. demonstrated a 26.12% increase in zinc content in chickpea seeds compared to the control, and an increase in zinc content from 12.61 to 16.09 ppm in tomato fruits after AMF inoculation[4].

Superior Secondary Metabolites

Plants naturally produce flavonoids, polyphenols, anthocyanins, and antioxidants as secondary metabolites. These healthy substances have been extensively researched for their anti-inflammatory, anticancer, anti-aging, and anti-microbial activities. Humans may be able to receive these health benefits without having to pay for pricey over-the-counter dietary supplements by bio fortifying crops using Biofertilizer. Compared to control treatments, strawberries that received AMF or PGPRs produced fruits that included generally greater levels of flavonoids, polyphenols, anthocyanin, and antioxidants. Intriguingly, Todeschini et al. reported that under sterile soil conditions, Pseudomonas inoculation increased fruit output and anthocyanin content whereas AMF inoculation promoted strawberry development.

Future research might thus choose a prospective group of advantageous bacteria to boost growth, yield, and secondary metabolite synthesis simultaneously. Despite this, further studies in a natural field setting are necessary to verify the findings. Agriculturally significant crops like tomatoes were treated with Biofertilizer containing Bacillus or Trichoderma, which also resulted in an increase in antioxidants, flavonoids, and polyphenols in the crops. Similar to this, after being treated with Azotobacter, Bacillus, or AMF, other crops including spinach and flax likewise showed elevated amounts of all three metabolites as described. Clinical investigations to determine the possibility of long-term ingestion of these nutritionally improved crops would be fascinating to do.

Enhancement of Vitamin Content

The most desired goals for bio fortification in crops are vitamins. The transgenic golden rice and the provitamin A-loaded orange-fleshed sweet potatoes are two excellent examples of bio fortification made possible by conventional breeding and genetic engineering, respectively. However, the protracted government licensing procedure for transgenic crops and the drawn-out breeding process call for urgently required study on the use of Biofertilizer to increase the vitamin A content of crops. The vitamin B group has also received attention recently due to reports of inadequacy in many developing countries with less varied diets. Plants can naturally absorb vitamins B1 and B12 from the soil, but they can only synthesis a little quantity of B1 and B9. There have been very few attempts to use Biofertilizer to fortify horticultural crops with vitamin B. Strawberries' vitamin B9 concentration was shown to rise after the co-inoculation of AMF and Pseudomonas. Improved B1 and B12 vitamin content was achieved by using microbial-rich organic wastes, such as cow dung, in the production of mung bean sprouts and spinach. It is necessary to identify microorganisms that can produce the B vitamins from cow manure in order to formulate these prospective microbes into Biofertilizer for the bio fortification of vitamin B in crops.

Fruits are the primary source of vitamin C. Most studies have shown that using Biofertilizer often increases the amount of vitamin C in fruits. Strawberries, lettuce, and tomatoes now contain more vitamin C thanks to the use of bacteria from the genera Phyllobacterium, Paenibacillus, Pseudomonas, and Glomus. In instance, strawberries treated with Pyllobacterium endophyticum had a 79% greater vitamin C content than the untreated control. In certain instances, following the inoculation of bacteria, the vitamin C content of fruits was decreased. For instance, strawberries' vitamin C content was decreased when Pseudomonas and Bacillus were co-injected. To make it easier to choose prospective bacteria for vitamin C fortification, further research into the processes of vitamin C production in plants during plant-microbe interaction is needed[5].

Enhanced Resistance to Biotic Stress

As sessile creatures, plants are vulnerable to a variety of biotic stressors, including invasion by weeds, insect pests, and plant infections. In contrast to current chemical treatments, sustainable disease management is preferable since it shields users and the environment from exposure to dangerous chemicals. Due to its good long-term impact on soil health and crop output, the use of Biofertilizer is growing in popularity among producers as a possible method of enhancing plant tolerance to biotic stress. In general, the interaction between helpful microorganisms and host plants, which is often followed by a host defensive reaction, results in crop tolerance to biotic stress. The use of Biofertilizer to boost horticultural crops' growth and productivity as well as their ability to withstand biotic stress is covered in detail in the section that follows.

Bacterial and Fungal Pathogens

Plant diseases often account for 25% of the world's yearly crop yield in crop losses. Plant diseases may be sustainably controlled utilizing soil- or plant-derived beneficial bacteria, via a process called as biological control, as opposed to using traditional and hazardous chemical techniques. Because the majority of these microorganisms were known to possess both PGP and biocontrol abilities, researchers were interested in developing them into Biofertilizer. There were many successful examples of using Biofertilizer to maintain the growth of horticulture crops despite the invasion of bacterial and fungal plant diseases.

Applying B. to tomato plants' leaves as a pre-treatment. Under glasshouse and field studies, methylotrophic us bacterial suspension increased plant biomass and fruit diameter while inhibiting Botrytis cinerea's growth by up to 60%. B. was added to the ordinary bean seeds. Additionally, Curtobacterium flaccumfaciens pv's overall vegetative development and disease control were enhanced by the subtilis suspension. From 42% to 76% of flaccumfa-ciens. By stimulating the jasmonic acid-dependent defensive response, as shown by the rise in phenylalanine activity, phenolics, and lignin accumulation, the pre-treatment of seed may have caused systemic response in the bean seedlings. B's use in this sentence. When three distinct Fusarium pathogens Fusarium verticillioides, F. subtilis also enhanced the germination of mung beans F. as well as Fusarium sp.However B. Although this strain of subtilis did not create chitinase, it did make surfactin, a lipo-peptide biosurfactant. According to Yan et al., surfactin aids in the formation of biofilms that shield microbial cells from hostile environments, improve microbial swarming motility to nutrient-rich rhizosphere, increase root colonization efficiency, and cause pathogen membrane performance leading to cell electrolyte leakage and, ultimately, cell death. Three bacterial pathogens, Pseudomonas syringae pv, have been effectively treated by using Lactobacillus plantarum, a lactic acid bacterium. Kiwifruit actinidiae, Xanthomonas arboricola pv. Xanthomonas fragrariae in strawberry and pruni in Prunus. The presence of bactericidal metabolites such lactic acid, plantaricin, and organic acids in the culture filtrate, according to metabolite analysis, may have a role in disease suppression. The precise role that these metabolites generated by lactic acid bacteria play in the biocontrol of plant diseases is still not fully understood[6]. Trichoderma genus fungal biocontrol strains are widely recognized for their biocontrol and PGP traits. In melon, eggplant, and chickpea, Trichoderma asperel-lum was shown to enhance growth and successfully eradicate the fungus Macrophomina phaseolina.

In peanuts, chili, and beans, as well as Fusarium solani. After the inoculation of T, tomato bacterial wilt induced by Ralstonia solanacearum was decreased to an average of 50% in the first and second years of planting. The asperellum. The first year's maximum tomato output of 6.93 t/ha was attained, while the second year's yield only slightly decreased to 5.82 t/ha, suggesting that the biocontrol's effectiveness may have declined. Continuous and long-term administration of the Biofertilizer may be more advantageous than a single treatment in order to maintain the population of biocontrol agents and the efficacy of the biocontrol. The inoculation of T. improved seedling development and tolerance of tomato seedlings against the fungus Sclerotic sclerotium. Is harzianum. Harzianolide is created by T. In pre-treated tomato seedlings, it was shown that harzianum increased the expression of genes related to the salicylic acid and JA-ethylene pathways. The initial step in the induction of ISR in tomato seedlings was the stimulation of PAL enzyme activity through the JA/ET signaling pathway, which is also a crucial regulator enzyme in SA production. As a result of the buildup of reactive oxygen species brought on by the oxidative stress caused by the fungal infection, the antioxidant activity was subsequently activated through the SA-signaling pathway[7].

Using a combination of several bacterial strains has been shown to increase the effectiveness of biocontrol when compared to using only one strain. A combination of two distinct B strains. Velezensis enhanced plant development and reduced the severity of the Xanthomonas axonopodis pv illness. Tomato with vesicatoria, Pseudomonas syringae pv. Tomato on tomato, pepper on pepper, Phytium ultimum on cucumber, and Rhizoctonia solani on tomato. The synergistic impact on disease suppression may have been caused by the synergistic synthesis of antimicrobial metabolites or enzymes by each strain in the combination. B. is based on a prior research that was done. Velenzensis strains developed particular antibiotic metabolites such haloduracin and bacillomycin, which, when combined, suppressed illness.

The disease incidence of Ralstonia solanacearum wilt in chilli plants was also reduced by up to 80% using a mix of Lysinibacillus, Bacillus, Azotobacter, and Pseudomonas, and plant growth enhancement was also seen in this research. P. aeruginosa and T. reesei together submitted an application. In addition to stimulating the development of banana plant vegetative, harzianum included in pesta granules has been shown to lessen the severity of Fusarium wilt in bananas by 66.67% when compared to traditional benomyl fungicide. A crucial part in the prevention of illness and the stimulation of plant development is played by changes in the soil microbiome brought about by the introduction of new microbial strains. B. Amyloliquefaciens, which was created using pig manure and neem cake as carriers, stabilized the total bacterial metabolic capability in carbohydrate, carboxylic, acid, and phenolics metabolism in soil while increasing banana output and reducing Fusarium wilt disease occurrences.

Since these substances might act as allopathic agents against plant pathogens, their microbial breakdown in soil may reduce the occurrence of disease. The use of B over the long term. A healthy and stable soil microbial population is required to support continuous cropping and sustained high crop yield, and amyloliquefaciens has also induced increased richness and variety of soil culturable rhizobacteria. In a subsequent investigation, the same strain was used, and via bacterial taxonomic specific suppression mechanisms, which are still being completely understood at this time, it also increased the rhizospheric soil bacterial population and improved disease suppression for over 3 years of field experiment.

A group made up of B. B. and Cereus. Subtilis were also suggested to affect pepper plants' soil microbiota. As a result, soil's organic and inorganic components are degrading, depriving plants and biocontrol bacteria of the nutrients they need to grow. The Bacillus microbial combination treated in conjunction with mushroom composts greatly increased the pepper fruit output and postharvest quality, and the control effectiveness against Rastonia wilt and Phytophthora blight in naturally affected fields was 76% and 81%, respectively. Additionally, the capacity of Bacillus strains to solubilate mineral elements into readily accessible potassium and phosphate just one planting season, has helped to keep the land fertile. Two bacterial strains of B. subtilis and C. By lowering R, velenzis and P. fluorescens significantly decreased tomato wilt disease. Increasing crop growth while reducing the solanacearum population. Changes in the soil microbiome were also observed, and it was hypothesized that the enhanced Actinobacteria population in the soil was responsible for the reduction of Ralstonia wilt[8].

They demonstrated that these strains aggressively colonized the roots and inside xylem vessels using confocal laser microscopy. Effective root colonizers often outcompeted plant pathogens, preventing the spread of agricultural illnesses. Additionally, the B's genome was sequenced. The anti-biotic biosynthetic genes for diacetyl-phlorolglucinol and phenazine, which have been extensively documented for their broad range antimicrobial efficacy against plant diseases, have been discovered in the velenzis and P. fluorescens species. Simply stated, the relationship between plant diseases, host plants, and beneficial microorganisms is dynamic and complicated. In order to accomplish the required biocontrol and PGP effects for the advancement of sustainable disease management, such interaction is often interrelated.

Viral Pathogens

With at least 450 distinct species, viruses are obligatory parasites that attack the majority of cultivated crops. The majority of these viruses are RNA viruses. 40% of all agricultural losses are thought to be caused by viral infection. Since insect vectors are a popular means of transmitting plant viruses, the current practice is to employ pesticides, which may pose long-term risks to the environment and public health. Pesticide prices are rising, and customers are demanding pesticide-free food, which has led to the introduction of sustainable alternatives to pesticides like Biofertilizer. Plant viruses can be controlled with the help of PGP bacteria found in Biofertilizer, which has also improved the vegetative development and productivity of a variety of horticulture crops.

After transplanting, banana bunchy top virus was decreased by up to 60% in tissue-cultured bananas bacterized with Pseudomonas and Bacillus. With pronounced accumulation of defense-related enzymes and pathogenesis-related proteins, foliar spraying tissue-cultured bananas with the same bacterial strains during the hardening and acclimatization stage also reduced BBTV infection, suggesting that these strains had a priming effect on activating the host defense response against viral infection. A Biofertilizer containing the same microbial strains decreased BBTV infection at 80% and 52%, respectively, under glasshouse and field settings. It also decreased the viral titer and enhanced yield by 53.33%. The high density of PGP bacteria in the rhizosphere throughout the growing season may have sparked a chain reaction of host defensive reactions and enhanced banana development by encouraging nutrient absorption. Other comparable studies also showed that, under field circumstances, banana plants infected with a single or a group of Pseudomonas, Rhizobacteria, and Bacillus enhanced yield and postharvest quality of banana.

Minor cucumber mosaic virus was discovered to inhibit virulent CMV infecting tomato plants, but it also results in 20% yield loss, minor stunting, and vigor decrease. Therefore, a combination of mild CMV with Pseudomonas, Stenotrophomonas, Azospirillum, or Anabena reduced the reproduction of virulent CMV with a disease severity reduction of up to 91.3% while simultaneously increasing tomato fruit output by 48% and 40% in glasshouse and field settings. According to Beris et al., triple soil drenching, foliar spraying, and tomato seed imbibition with B. The severity of the tomato spot-ted wilt virus was lowered by amyloliquefaciens from 50% to 80%. Additionally, since the potato virus Y was detected later in the apical leaves, the accumulation of the virus in tomato was also decreased. Following B inoculation, tomato plants infected with TSWV and PVY showed increased expression of SA-induced PR proteins. Although the expression of JA-induced genes was insignificant, amyloliq-uefaciens

SA and JA signals are used mostly by plants to defend themselves against viruses. Through the activation of the mitogen activated kinase cascade, SA is essential for systemic resistance because it causes the overexpression of the NPR1 gene, which in turn causes the transcription of the PR genes and the RNA silencing antiviral mechanism[9]. Spraying bacteria from phyllospheres on the leaves, B. Over the course of a three-year field study, amyloliquefaciens decreased the relative contents of CMV coat protein RNA before the viral infection. The association between viral tolerance and PR gene overexpression in pepper plants suggests that SA defensive signaling was increased. There was a decrease in naturally occurring viruses such pepper mottle and broad bean wilt. After P. oleovorans was applied, the seed transmission rates of cucumber green mottle mosaic virus and pepper mild mottle virus in pepper and watermelon seeds were decreased. Since the culture filtrate of P. oleovorans modified the aggregation of the viral protein required for seed-to-seed transmission, the subcellular localization of PMMoV's mobility protein was also eliminated.

According to the study, using PGP microbes may also interfere with the production and translation of sub genomic RNA, which encodes the viral coat protein, affect the assembly and disassembly of viral particles, and cause the microbial proteasome to degrade free CP. According to one research, pre-treating cucumber plants with Stenotrophomonas maltophilia prevented the virus from reproducing for more than 3 days and suppressed the expression of the viral protein genes in the leaves. According to Maksimov et al., the majority of PGP microbes also produce extracellular RNases that break down viral particles, bacterial barnases that have antiviral activity, and microbial surfactants that activate the SA defense signaling pathway when a virus is present. These potential antiviral mechanisms caused by PGP microorganisms have not yet been thoroughly explained, and this knowledge might be useful in the future for creating Biofertilizer with desired antiviral qualities.

Pest Insects

Each year, insect pests cost the agricultural industry a total of US$17.7 billion in lost revenue. Due of their efficiency, pesticides are still frequently used. However, the use of beneficial microorganisms with insecticidal characteristics to control pests in a sustainable way has been motivated by the negative effects of pesticides on users, the environment, natural predators, and the growth of resistant insects. The use of Biofertilizer containing certain microbial strains or a group of them, which have the dual properties of boosting crop tolerance to diverse pest infestations and stimulating crop development, has also started to draw attention.

By delaying the rate of reproduction of female cotton aphids, Aphis gossypii, and cucumber seeds ingested in bacterial suspension of P. fluorescens strain PF169 showed increased yield of cucumber by 58%, promoted early mat-uration of plant by shortening the flowering time, and most importantly, reduced the population growth rate of aphids. Tomato seeds ingested by P. putida enhanced plant biomass and yield by 60% and 40%, respectively, and reduced cotton leafworm infection. According to biochemical study of tomato plants, antioxidant activity was increased and protease activity was boosted, which may be a sign that proteinase inhibitors that are harmful to S. spp. larvae have accumulated. Litura when grazing on leaves

In comparison to the inoculation of a single microbial strain, Biofertilizer containing a combination of Glomus, Rhizobacterium, and Pseudomonas dramatically enhanced the biomass and production of Faba beans and decreased the aphid population by 71.3%. In contrast, Glomus mosseae and G. both received vaccinations. Fasciitum did not shrink. The root-feeding black vine weevil Otiorynchus sulca-tus' larval survival, which leads to poor strawberry plant performance, including decreased plant, root biomass, and runner output. Without colonization with specific strains, this undesirable impact might be reversed by ensuring that 88% of eggs do not hatch into fully developed larvae. According to Gadhave et al., incompatibility and competition between various strains may have caused inadequate root colonization and, in turn, diminished the host's ability to defend itself against insect invasion.

The colonization of B. cerevisiae aims to trigger the host defensive reaction against silverleaf white-flies. Tomato plants with the subtilis strain BsDN activated a long-term ISR via JA signaling. A mix of JA-dependent and JA-independent defensive mechanisms are used in the resistance response. When an insect feeds, JA-dependent pathways create host anti-nutritive proteins such proteases and proteinase inhibitors while suppressing SA-signaling to promote host tolerance. Protein digestion is impeded by proteinase inhibitors' action on insect midgut proteinases, which postpones the release of peptides and amino acids from ingested protein. This results in mortality ultimately due to poor and stunted development. The same research employed mutant tomato plants that were unable to generate JA to see if plants might develop a comparable degree of resistance to B. tabaci. Intriguingly, genes implicated in the photosynthetic, phenylpropanoid, and terpenoid biosynthesis pathways as well as a Hsp90 chaperonin were increased, which may have mediated the tomato plants' resistance to pests while downregulating their susceptibility to pathogens and their level of hypersensitivity. In order to fully comprehend the JA-independent route in a tripartite link between plants, PGP microorganisms, and insect pests, further research is necessary.

Weeds

In the agricultural sector, weeds are a significant issue since they cause a 37% drop in crop output. Herbicide treatment is a prevalent method of weed control that has produced weed biotypes that are resistant to herbicides while also posing several health and environmental risks. A possible option to minimizing chemical use is biological weed control utilizing rhizospheric bacteria. In addition to eliminating typical weeds present in horticulture settings, it has been shown that bacterial or fungal strains isolated from the rhizospheric zone may also maintain or boost crop output. The emphasis in the sections that follow will be on various bacterial and fungal strains that have been used to control weed development and/or to increase or sustain the production of some horticultural crops[10].

Under glasshouse conditions, P. aeruginosa strain KC1 decreased the biomass of two weeds, spiny amaranth and common purslanes. This strain produced hydrogen cyanide, which prevents the formation of roots. Metal complexes with functional groups of plant enzymes involved in various key metabolic processes, such as respiration, nitrate and carbon dioxide absorption, as well as glucose metabolism, develop when cyanide is present. Additionally, cyanide interacts with a particular protein called plastocyanin, which may prevent electron transfer during photosynthesis. Additionally, the WSM3455 strain of P. fluorescens generated HCN, which decreased the biomass of wild radish by 53.2%. The grapevine plants were not significantly harmed by the treatment of this strain. Another P. fluorescens strain, G2-11, increased soybean growth while suppressing the development of barnyard grass and green foxtail weeds by up to 62.0% and more than 77.0%, respectively, in field settings. Soybean root and shoot growth reductions were only reported to be 6.5% and 1.2%, respectively.

By reducing the development of shoots from seeds by 64% and 76%, respectively, P. fluorescens strain G2-11 also inhibited two species of broomrape weeds. The same strain has been shown to have two distinct functions by shortening the Faba bean plant's blooming period by up to 11 days and increasing the quantity of flowers by five times. Microbes emit certain chemical substances that prevent weed development. For instance, the P. fluorescens strain WH6 developed a substance called "Germination Arrest Factor" that prevented grassy weed seeds from germinating when coleorhiza and plumule emerged. The chemical name of the substance was eventually determined to be 4-formylaminooxy-L-vinylgylcine, and it was discovered that it interfered with many enzymes, including those involved in ethylene production and nitrogen metabolism, that need pyridoxal phosphate as a cofactor. In contrast to dicot plants, several grass species that were cultivated for food and seed were reportedly more vulnerable to GAF. This microbial strain might be used on dicots to control the emergence of grassy weeds rather than graminaceous crops. By producing two herbicidal substances known as pseudophomin A and B, P. fluorescens strain BRG100 used in pesta granules also reduced the activity of green foxtail weed. It is yet unclear how the chemicals are made and how they prevent weed from growing.

The 5-aminoleveulinic acid biosynthesis carried out by B. The Indian mustard plant biomass was increased by the flexus strain JMM24, but the yellow vetchling weed plant biomass was lowered. High concentrations of ALA have been discovered to disrupt and degrade vital cellular organelles such the mitochondria, thylakoid, and chloroplast while also lowering antioxidant activity in the cells, which results in cell death. Morning glory seedlings' root development was likewise inhibited by Bradyrhizobium japonicum strain GD3's high concentration of IAA, which was 64 mM. Transmission electron microscopy showed that vesiculation, cytoplasmic disarray, and cell wall breakdown were the causes of the dam-aged root cells. IAA may limit root and shoot development, reduce internode length and leaf growth, intensify the green pigmentation on leaves, close the stomata, and enhance ROS generation when present in dangerous amounts. Trichoderma virens generated viridiol, a phytotoxic substance that prevented the development of grassy and broadleaf weeds without significantly reducing the vigor and output of agricultural crops like pumpkins and tomatoes. However, the precise mechanism by which viridiol suppresses invasive weed has not yet been identified.

Increased Resistance to Abiotic Stress

Agricultural land is under risk from climate change-related temperature variations, salinization of the land, erratic rainfall, and heavy metal contamination of the soil. Because of these adverse abiotic factors, such as drought, salt, heavy metal toxicity, cold, and heat stress, crops are negatively impacted. As a result, their yield may be reduced by as much as 70%.

Utilizing microorganisms as biofertilizer has shown encouraging outcomes in assisting horticulture crops to overcome abiotic stress via a variety of ways.

Global warming and drought are both natural conditions marked by a water shortage that have an impact on agricultural production worldwide. Inadequate water consumption hinders agricultural development and output, which is bad for global food security, especially in poor nations. By the year 2050, it is anticipated that drought would hinder agricultural production on more than 50% of the world's arable farmlands. Beneficial microorganisms with PGP and drought-tolerant properties are now used to increase the growth and productivity of horticultural crops when there is a water shortage. Applying these microorganisms as biofertilizers might be a potential option to assist crops survive with drought stress since they are widely distributed in many soil conditions, including the dry and arid areas. After seed bacterization with P. putida, chickpea seed germination under polyethylene glycol-induced drought stress was enhanced. Enhanced anti-oxidant activity to reduce oxidative stress and better root development are three characteristics of P. putida induced drought tolerance in chickpea. Penicillum sp. and Phoma glomerata are endophytic fungi. Generated phytohormones such gibberellic acid and IAA that improved cucumber growth.

Regarding Horticultural Crops and Biofertilizers

Drought-induced growth in both shoot and root tissue while also enhancing the absorption of vital minerals including potassium, calcium, and magnesium. Since the rubisco enzymatic activity involved in photosynthesis was maintained after 13 days of water deprivation, cucumber plants treated with a consortium of Bacillus and Serratia displayed deeper green leaves and reduced wilt symptoms. The microbial 1-aminocyclopropane-1-carboxylic acid deami-nase produced by Variovorax, Achromobacter, and Pseudomonas alleviated the negative effects of ethylene accumulation as a result of drought stress in pea and potato plants, resulting in plants with better plant vigor and root growth than uninoculated plants. Grapevine plantlets contaminated by B. Under drought stress, licheniformis and P. fluorescens showed 76-fold and 40-fold increases in abscisic acid levels, respectively, compared to the un-inoculated reference.

Higher amounts of ABA are often seen during droughts, which cause tomatoes to close and lower transpiration rates. The synthesis of secondary metabolites like terpenes rose in grapevines 20 to 30 days after bacterization. Terpenes are thought to have a protective function in maintaining the integrity of cellular membranes and possess antioxidant characteristics that sequester free radicals. However, additional research must be done to fully comprehend how terpenes work with molecular tools to reduce abiotic stress. Following the application of B, ornamental plants like lavender showed better drought resistance. Thuringiensis in an arid setting. The K+ ion, a crucial osmolyte that controls water homeostasis, stomatal opening, osmotic potential, and transpiration under drought stress, greatly increased the potassium, K, content in lavender.

In addition, cytokinin, a phytohormone, is crucial for drought stress resistance. Endogenous cytoki-nin levels in plants fall under drought stress, which favors root development and encourages stomatal closure to slow transpiration. In order to compensate for the loss of endogenous CK in plants, CK-producing microorganisms may be used, increasing drought resistance. Due to the inoculation of CK-producing Methylobacterium, enhanced CK levels in lentil under drought spurred early development of shoots and roots, increased photosynthetic rates, and boosted yield by at least 4-fold. In a related investigation, under conditions of water deficiency, lettuce seedlings treated with CK-producing Bacillus boosted the shoot biomass by 50%. Following B inoculation, the ornamental Oriental Thuja plants likewise showed elevated CK levels. Subtilis, with seedling leaves displaying increased relative water content under drought-stricken conditions.

A crucial characteristic that enables bacteria to build biofilm as a barrier against drying and changes in water potential is the creation of microbial extracellular polymeric materials. According the treatment enhanced sunflower plants' capacity to withstand drought conditions because the microbe produces EPS that aggregates dirt around the roots, enhancing plants' ability to absorb water and nutrients from the soil. The complete genome sequence of rhizobacterial strains has enabled the discovery of genes involved in the development of symbiotic relationships, nitrogen fixation, and drought resistance. These two strains have effectively enhanced soybean seed germination in drought-stricken environments created by 4% PEG. The sequencing data may be used further in the future to better understand how microbes and hosts interact when there is a drought, allowing for the expansion of agricultural production into semi-arid and desert areas.

Salinity

Salinity has an impact on almost 50% of the world's 5.2 billion hectares of agricultural land. Sodium chloride, the main component of salinity or salt stress, is hazardous to plants at high concentrations of the Na+ and Cl ions. Conventional techniques for reclaiming salt soil, such as scraping, leaching, flushing, or amending with chemicals, have only patchy effectiveness. This necessitates the application of sustainable methods, such as salt-tolerant microorganisms, to increase the resistance of horticulture crops to salt stress. PGP microbes use a variety of mechanisms to reduce the detrimental effects of ethylene caused by oxidative stress in crop plants, including the production of a variety of phytohormones like IAA, gibberellins, and cytokinins, the synthesis of ACC deaminase, the production of exopolysaccharides or biofilm as a barrier for host plants, the regulation of host cellular sodium and potassium levels to achieve homeostasis in o.

The co-inoculation of Azospirillum and Rhizobium also boosted the production of nod gene inducing flavonoids, which encouraged root nodulation in salty conditions, and root branching in common bean seedlings. Azospirillum, in particular, permits a longer, more persistent exudation of flavonoids from the root, which works to activate nod genes and cause nodulation in bean roots. Inoculating different horticultural crops, such as tomato, cucumber, pepper, and okra, with PGP microbes from the Azopirillum, Enterobacter, or Pseudomonas genus improved plant biomass, increased K+ cellular content, enhanced root growth for nutrient absorption, and increased yield. Intriguingly, these experiments also showed that PGP microorganisms may increase the chlorophyll content and rate of photosynthesis in inoculated plants under salt stress. According to Yan et al., tomato plants infected with P. putida had elevated expression levels of the Toc GTPaces or the chloroplast protein import apparatus. This may make it easier for chloroplast development to import nucleus-encoded proteins from the cytoplasm, showing that photosynthesis-related pathways were unaffected by salt stress.

Heavier Music

High levels of heavy metal contamination in soil are often linked to mining operations, overuse of chemical fertilizers, the application of sewage sludge, and the dumping of heavy metal waste. Heavy metals that may eventually make their way to people via the food chain are absorbed and accumulated by plants. Additionally, plants are subject to heavy metal stress, which has detrimental impacts on their cellular structures and metabolism. Applying biofertilizers containing PGP microorganisms that are heavy metal-tolerant is an appealing strategy to increase crop resistance to heavy metal stress. Metal transport across the cytoplasmic membrane, bio sorption and bioaccumulation on microbial cell walls, metal entrapment in cellular structures like vacuoles, precipitation of heavy metal, and metal detoxification via cellular oxidation-reduction are all components of microbial bioremediation of heavy metal.

Grapevine plantlets were contaminated by B. and Micrococcus luteus. Licheniformis increased the host's antioxidant activity, which boosted biomass and shielded the plants from oxidative stress brought on by elevated cadmium concentrations. Bradyrhizobium japonicum, a heavy metal resistant strain, extended lettuce shoot and root lengths.

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Seedlings stressed by nickel, copper, or lead. Further analysis of the bacterium's FTIR spectrum revealed that the presence of amine and nitro functional groups on the membrane was shown to be the catalyst for metal bio sorption, lowering the bioavailability of heavy metals for plant uptake. Plants of the soybean species Bradyrhizobium sp. also suggested enhanced photosynthetic pigments and a rise in carotinoid concentration to lessen chlorophyll pigment photo-oxidation under Cd stress. Reduced Cd concentration was also seen in the roots and shoots of inoculated plants. This microbial strain may create sidero-phores to sequester vital minerals for host absorption since increased magnesium and iron levels in soybean plants were also seen.

Due to the capacity of a group of Pseudomonas and Bacillus to create the growth hormone IAA, the plant biomass of spinach was also greatly enhanced with a reduction in the accumulation of Cd, Pb, and Zn. After being treated with P. aeruginosa and Burkholderia gladioli, tomato plants grown under Cd stress did not develop significant amounts of Cd in their roots and shoots. When infected with both PGP bacteria, the metal transporter gene in tomato did not express itself to a high degree either. Following bacterial inoculation, metal chelating compounds in tomato plants, such as total thiols and non-protein bound thiols, were likewise elevated under Cd stress. The mechanism behind the microbial control of the metal transporter gene and the synthesis of metal chelators in plants, however, is yet unknown. AMF, like R. Better than F, intraradices colonizes pepper mosseae exposed to a Cu stress. The AMF strains maintained heavy metals on the cell walls of the mycelia and blocked metal transfer to shoots via metal chelators. Following Trichoderma inoculation, there was a decrease in the amount of arsenic in chickpea seeds and a host's resistance to as stress. Heavy metals in soil are said to be methylated by trichoma, and methylated metals in soil are decreased through volatilization into the air.

Frozen Stress

Since they are grown in tropical and subtropical locations, many horticulture crops, such as tomato, soybeans, and legumes, are unable to withstand freezing temperatures. Plant growth and development are severely hampered by cold or chilling stress, which also prevents certain plant species from being planted in cold climates and reduces agricultural output. In terms of plant physiology, cold stress slows down cellular metabolism, builds up reactive oxygen species, lowers cellular osmotic potential, hardens the plasma membrane, and destabilizes protein complexes involved in metabolism. Microbial inoculants or Biofertilizer have been effectively used to increase a crop's resistance to low temperatures, allowing crops to tolerate cold stress.

Burkholderia phytofirmans, an endophyte, bacterized grapevine plantlets in vitro, and they were able to endure 4°C temperatures. Plants that had been bacterized had increased biomass, less electrolyte leakage due to the thickening of the xylem cell wall, higher levels of secondary metabolites such phenolics and proline, a faster rate of photosynthesis, and more starch being deposited. By upregulating stress-related genes and metabolites, the grapevine plantlets' bacterial priming effect also helped them become more tolerant to low temperatures, demonstrating the importance of the endophyte in the plantlets' adaptation to the cold. Additionally, B. It was discovered that phytofirmans caused cell wall strengthening, preventing cell collapse brought on by the production of inter-cellular ice crystals. At 15°C, tomato seedlings bacterized with the cold-resistant Pseudomonas of Flavobacterium grew effectively. In bacterized plants, cold tolerance was also attained as shown by the decrease in membrane damage, activation of antioxidant activities, and accumulation of proline in the plants.

Similarly, reduced membrane disruption, lower ROS levels, and elevated expression of cold acclimation genes were indicators of chilling resistance in tomato plants bacterized with cold-tolerant Pseudomonas. Inoculating cucumber and tomato plants with the AM fungi Funneliformis mosseae and Glomus mosseae reduced plant mortality, increased plant biomass, increased production of secondary metabolites, enhanced ROS scavenging activity, and increased the expression of stress-related genes during chilling stress. The common bean's root water absorption was inoculated with Glomus sp. was not altered by 4°C either, indicating that AMF fungus may have the ability to prevent root cell membrane damage caused by cold stress.

Additionally, by preventing the buildup of endogenous ethylene in stressed plants, cold tolerance was attained. In a research, ACC deaminase, an enzyme that lowers the synthesis of ethylene, was produced by a cold-tolerant P. putida, which helped canola thrive under cold stress. The buildup of ethylene under cold stress is undesirable since it can hasten the pace at which plants senescence. Most Biofertilizer research on improving crop tolerance to cold stress is still in its early stages as of right now. To fully comprehend the function of host defense signaling and metabolic, further investigation should be made. When crops are treated with Biofertilizer, they are more likely to be able to withstand cold temperatures.

Warmth Stress

By 2100, temperatures are expected to rise to a range of 1.5°C to 5.8°C due to global climate change. High temperatures have had a significant negative influence on plant growth and development, especially on agricultural output and quality. There are various examples of employing Biofertilizer to enhance plant tolerance to heat stress while sustaining or boosting the yield in order to combat heat stress in crops. PGP bacteria from the genera Pseudomonas, Bacillus, and Orchrobactrum have been shown in many studies to enhance heat tolerance in cereal crops like wheat while also enhancing grain production under heat stress conditions. Surprisingly, research on the enhancement of horticultural crops' thermo-tolerance by the use of Biofertilizer is still inadequate.

There is currently just one research that made use of B. to increase the ability of soybean plants to withstand thermal stress of up to 38°C using aryabhattai. The PGP bacteria was discovered to create exogenous absisic acid from this investigation, which also controlled the host's natural ABA.

The outcome was that the bacterially treated soybean plants had increased ABA concentrations, which caused the stomata to close in a heat-stressed situation to stop additional transpiration. Research should thus be focused on horticulture crops to avoid possible economic loss in the face of climate change since bio-fertilizer is a promising strategy to avoid heat stress in plants.

Increased effectiveness of vegetative reproduction

Growth from Cuttings

Cuttings are used in the vegetative propagation of horticultural crops to provide clonal planting materials. Since no rootstocks are required, this technique may be used instead of grafting. Additionally, because some seeds fall into dormancy, germination is not necessary. Synthetic auxins, which function similarly to natural plant rooting hormones but may be hazardous to plants at high concentrations, are often used to help root difficult-to-root species. Applying PGP microorganisms to cuttings to substitute toxic chemicals has gained interest because to their capacity to create rooting hormones like IAA to speed up the rooting process of cuttings. Cuts of black pepper dipped in B. cuttings with more roots and plant biomass were formed after being exposed to tequilensis for 30 minutes. The kiwifruit semi-hardwood stem cuttings were enhanced by bacillus strains by 47.5%, and the hardwood stem cuttings by 42.5%. The cuttings' youth may be the cause of the variations in rooting capacity. Given that differentiated cells in the juvenile cuttings may flip over and develop into adventitious roots, juvenile cuttings may exhibit more cellular flexibility than matured cuttings.

Compared to the typical approach, grapevine cuttings treated with Azospirillum brasilense had better rooting characteristics in terms of the quantity of roots, root architecture, and biomass of vines. Additionally, it was shown that rooting with PGP bacteria depends on cultivar, with certain grapevine cultivars not responding to the microbial inoculation. Koyama and colleagues found that when A. When brasilense was used in conjunction with 3 g/L IBA, more adventitious roots were seen in olive tree cuttings, but other treatments did not substantially vary in terms of the proportion and survival of rooted cuttings. Further testing is necessary to determine if the addition of IBA affected the rhizobacterte-ria's ability to produce natural IAA. Some strains, including Pantoea sp. independent of the inoculation techniques and three test varieties of olive, provided better rooting rates in olive cuttings. Interestingly, this strain does not create as much IAA as Pseudomonas and Bacillus, but it synthesizes ACC deaminase, which lowers ethylene buildup after injury and prevents ethylene from inhibiting root growth. Most research on horticultural crops' vegetative propagation utilizing PGP microorganisms is still in its early stages. Indeed, more thorough experimental designs should be used to investigate the influence of cultivar/genotype on microbial colonization behavior, aspects that influence microbial IAA production, the uptake and transport of exogenous auxin in cuttings exposed to PGP microbes, and auxin signaling pathways during the rooting process after inoculation. These details can be helpful in hastening the vegetative growth of horticulture crops.

Grafting

Grafting is often utilized in current agricultural systems to provide pathogen resistance, alter plant physiology, give disease or pest resistance, and tolerate certain soil types. Fruits, ornamental plants, and vegetables benefit from grafting because it improves their ability to absorb and use nutrients. Compared to rooted plants, the rootstocks are more effective in absorbing water and ions.

Agricultural Crops and Biofertilizers

Was delivered to the aboveground scion using water and ions that were produced from cuttings. Given the advantages of grafting for farmers, a number of grafting techniques, including the use of PGP microorganisms, have been developed to increase the success rate of grafting union between rootstocks and scions. Application of both P. putida and B.

Compared to single inoculation and control treatments, simplex produced 100% callusing and graft survival rates. The natural plant growth regulator, IAA, which is generated by the microbial strains, may be the cause of the quicker rooting of bacterialized graft shoots compared to controls, which are better developed and have thicker shoots. IAA encourages vigorous cell division, which results in the production of calluses, which later differentiate into adventitious roots. Additionally, Köse et al. immersed the scion for at least 3 hours in various strains of Pseudomonas and Bacillus, and the results of the grafting process revealed a success rate ranging from 80% to 93.3%. Similar to other strains, these two were known to generate IAA and ACC deaminase, both of which decreased the host's ethylene levels to promote callus production. Through foliar spraying of B, cacao grafting was enhanced to 62% as compared to water treatment. Suspended subtilis on the corrupt unions. The impact of these PGP bacteria on other horticultural crops is currently a subject of little investigation, and it is yet unknown how callus and root differentiation affect graft union.

Future Outlooks and Upcoming Challenges

It is clear that Biofertilizer' promise extends beyond just boosting the development and output of horticulture crops. Through microbial-mediated defensive response, stress tolerance for various biotic and abiotic stress of crops was also significantly increased. Through the use of vegetative propagation, Biofertilizer are also effectively used to enhance horticultural planting materials. Despite this, a wide range of conditions continue to have an impact on how well Biofertilizer perform consistently. In-depth summaries of the factors that contribute to ineffective bio fertilization and suggestions for solutions were provided in Table 2.2. Non-reproducible Biofertilizer application outcomes have been linked to crop genotypes, physiological age, application technique and frequency, viability counts, and pollutants in commercial Biofertilizer. The partnership between academics and industry on the manufacturing of Biofertilizer and the dissemination of information to farmers, which is most vital, has also gotten less attention, with the focus often being restricted to lab-scale optimization and production of Biofertilizer. Farmers' social input is also crucial so that continuous improvements may be made to the Biofertilizer' quality. For producers to profit from the sustainable and regular use of Biofertilizer instead of largely depending on chemical fertilizers, effective bio fertilization on horticultural crops requires a careful evaluation of various elements.

CONCLUSION

In fact, Biofertilizer have benefited the horticulture sector by guaranteeing that crop yield is maintained in the face of unpredictable environmental factors. However, many of the studies examined in this chapter's study still exhibit contradictions. Future research should focus on developing a comprehensive understanding of the processes and variables that impact how effective Biofertilizer are in order to close the knowledge gap. On the other hand, policymakers should impose strict restrictions to guarantee that the Biofertilizer have complied with the appropriate standards before being commercialized. Stakeholders should also take a proactive role in educating farmers and closely monitoring the results of field experiments. Combining these methods would promote the use of Biofertilizer as a sustainable alternative to chemical pesticides and fertilizers.

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CHAPTER 3

BIOFERTILIZERS' N2 FIXATION

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ABSTRACT:

The usage of inorganic chemical-based fertilizers poses a major hazard to both the environment and human health in today's soil management practices. Biofertilizer has been acknowledged as a replacement for synthetic fertilizers in sustainable agricultural areas for increasing crop yield and soil productivity. Rhizobacteria, which promote plant development, phosphate and potassium solubilizes, nitrogen fixers, cyanobacteria, ecto- and endomycorrhizal fungi, and other helpful microorganisms are often utilized as Biofertilizer ingredients. Utilizing Biofertilizers improves nutrient absorption, nutrient availability, plant tolerance, and plant development in response to both biotic and abiotic factors. These Biofertilizers will be crucial in helping to safeguard the environment, maintain soil production, and provide agriculturalists with cost-effective, eco-friendly contributions. The usage of synthetic fertilizers leads to increased soil destruction and environmental damage in the immediate area. Because of their capacity to fix nitrogen, microalgae are considered good Biofertilizers that have both financial and environmental advantages. The use of Biofertilizer in N-supplemented or N-limited circumstances is suggestively supportive of the root and shoot growth of soybean, cowpea, and mung bean. The importance of Biofertilizer inputs on nodulation, plant development, intake of nitrogen, potassium, and phosphorus, nitrogen fixation, and seed yield will be covered in this chapter.

KEYWORDS:

Biofertilizer, Eco-Friendly, Nitrogen Fixation, Nodulation, Plant Growth.

INTRODUCTION

Due to their uses in local consumption and export, substantial cash crops and leguminous crops are in greater demand globally. About 4.6 billion hectares of pulses are propagated annually across all areas and states. About one-third of the protein in grain legumes comes from the protein in human diets. Legumes are a significant rich source of protein due to their unrivaled ability to capture large quantities of biological nitrogen via biological symbiotic nitrogen fixation. Legume-rhizobia symbiosis may thus be able to provide a straightforward, low-cost means of enhancing harvest production. The vaccination of the soil with Rhizobium strains may increase legume output, nitrogen uptake, and nodulation. Rhizobia, which are involved in biological nitrogen fixation, are used to convert molecular nitrogen into ammonia in the process of nitrogen fixation[1].

The usage of BNF, which is crucial for agronomy in this region, reduces the need for artificial nitrogen fertilizers. Nitrogen is crucial for the enhancement and maintenance of crop production and development. Although, in agriculture, the continued use of superfluous chemical fertilizers has unexpected ecological repercussions, such as the destruction of soil organic matter and soil fertility as well as decreased nutrient use efficiency and water and nutrient embracing capabilities. Rhizobium inoculants are quite inexpensive and are used in the production of leguminous crops. By lowering the use of chemical fertilizers, the use of efficient inoculants may be seen as a crucial strategy for a reduction in ecological issues and sustainably managing. The following routes of development seem to be supported by several viable PGPB inoculants:

1. Biological Stimulants,
2. Biofertilizers, Alternatively
3. Bio Protectants

The use of Biofertilizers increases soil productivity, which increases crop by 16%–60% by promoting nodulation capacity in the soil, solubilizing insoluble phosphates, fixing atmospheric nitrogen, and manufacturing compounds that support plant growth. Rhizobia are mostly used as Biofertilizers because they adapt to ecological conditions and enable their productive nodulation and durability via the host plant.

Biofertilizers' N2 Fixation

The most significant issue limiting agricultural productivity among resource-poor farmers in developing countries is soil infertility. The maintenance of soil quality might be managed in large areas of the globe that promote the fundamental principles of moral agriculture education. The effects of deteriorating soil include the following:

1. Rapidly declining manufacturing levels,
2. Decreasing soil productivity,
3. Lessen the problems caused by land scarcity.

Due to ecological and biological problems, reduced nitrogen fixation and declining soil productivity are following the dead harvests in legumes. BNF demonstrates a significant role in the production of non-legumes as well as legumes, which are the primary source of nitrogen for farmers with minimal fertilizer, and establishes the highest potential solutions. Because of the increased population, it produces a meager yield by using inorganic chemical fertilizer, which led to a decline in soil productivity by the continuous farming of the same plot of land year after year. Chemical fertilizers are made from the indicated quantities of potassium, phosphorus, and nitrogen; their usage led to groundwater and air pollution. The use of chemical fertilizers poses a risk of groundwater and air pollution, while pesticides increase soil acidification.

By destroying plant roots, it also makes them susceptible to undesirable diseases. In addition, several attempts have been undertaken to produce Biofertilizer rich in a variety of nutrients in order to assure bio-safety. Biofertilizer has been accepted as an alternative to chemical fertilizer in sustainable agricultural areas to increase soil productivity and crop production. These prospective Biofertilizers play a significant role in soil sustainability and production for farmers, as well as in protecting the environment via their lucrative and biodegradable contributions.

In the soil, different bacteria are as abundant as rhizobia plants. A substantial portion of these microorganisms create a thorough organization and have a beneficial relationship with plants, which contributes to the growth of plants. These Biofertilizers maintain an abundance of incomplete types of micro and macronutrients in the soil through the mineralization or solubilization of potassium and phosphate, nitrogen fixation, biodegradation of biological substance in the soil, declaration of development adaptable matters in plants, and production of antibiotics.

Origin

Biofertilizers including Azotobacter, blue-green algae, Rhizobium, and Azospirillum were formerly often used. Farmers consistently passed on their expertise of practical bacterial inoculum from peer group to peer group. The efficacy of Biofertilizer, which was first shown by the manufacture and cultivation of small-scale compost, has been established. This has the effect of accelerating the degradation of agricultural harvests and organic deposits while providing a robust crop production.

The discovery of Azotobacter, followed by the discovery of BGA and a variety of other microorganisms, led the agronomic Nobbe and Hilther to commercially present the origin of biofertilizers in 1895 with the introduction of "Nitragin." To date, these bacteria have been exploited as biofertilizer. Biofertilizers often come with transporter-founded inoculants that contain effective bacteria. Microbes used through biofertilizer comprise K-solubilizers, for example, Bacillus mucilaginous, N-fixers, for exam-ple, Rhizobium Spp., Azotobacter chroococcum, and Cyanobacteria, plant growth-promoting Rhizobacteria , P-solubilizers, for example, Aspergillus fumigatus, Bacillus megaterium, sulfur oxidizers , and Vesicular-Arbuscular Mycorrhiza , for example, Glomus mosseae[2].

Biofertilizer: Constituents of Transporters

In order to increase the effectiveness of Biofertilizers, they are often changed via transporter modification, which also increases water ration capabilities. According to Somasegaran and Springer, a good transporter should have the following characteristics:

1. Easily sterilisable by gamma radiation or autoclaving,
2. Easily obtainable and reasonably priced in sufficient numbers,
3. Practicable and non-toxic to both microorganisms and plants,
4. Easy to create and should not include materials that form lumps,
5. A respectable water-holding capacity of at least 50%,
6. A respectable ability for absorbing moisture,
7. Enough capability for pH buffering,
8. Adequate seed adhesion,
9. Increased biological material content.

The combination of bacteria attached to transporter components enables the biofertilizer to be managed easily, efficiently, and over a long period of time. The disinfection of transporter components, such as talcum powder, sawdust, earthworm castings, and manure, is essential to maintaining large numbers of inoculants, according to extensive storage of time. Gamma-irradiation is the recording technique of transporter disinfection due to the disinfection method variations, which create no change in the chemical and physical belongings of the significant. Similar to that, autoclaving is another method for disinfecting transporters. However, autoclaving, which may change the properties of certain transported materials and kill particular bacterial types, can also be used to produce harmful compounds.

Mechanism of Biofertilizer Actions

Among the PGPR species, it was suggested that Azospirillum would release auxins, ethylene, and gibberellins. When administered using Paenibacillus polymyxa bacteria, the elevated levels of IAA in the roots of lodge-pole pine might also induce the manufacture of phytohormones. The Bacillus and Rhizobium were beginning to produce IAA in the presence of a carrier material, i.e., agricultural waste, at various temperatures and pH levels. Unlike other phytohormones, ethylene is responsible for dicot plants' restriction of growth[3].

DISCUSSION

Biofertilizer Advantages versus Biochemical Fertilizers

Inorganic fertilizers offer the benefit of quick action and low cost because to their quick nutrient release. As a result, they have become quite commonplace all throughout the globe. However, the findings indicated that they had negatives that could not be overlooked, thus much research has been done on the limitations of inorganic fertilizers. The use of inorganic fertilizer resulted in severe problems with various types of pollutants and crops grown in our typical environment. Because of their increased water solubility and ability to be deeply absorbed into soil that plant roots cannot reach, inorganic fertilizers were helpful in the soil contamination process.

Bio-fertilizers contain a wide range of long-lasting qualities due to the purposeful release of nutrients. By consistently using Biofertilizer, which corresponds to the buildup of nutrients in the soil, the overall soil productiveness is increased. Biofertilizers may be used to manage a number of plant diseases, including frost wilt, pythium root rot, parasitic nematodes, and Rhizoctonia root rot. By using Biofertilizer, which acts as a soil conditioner by adding organic matter to the soil, the soil particles are coordinated with each other and increase their ability to retain water, preventing erosion, desertification, and soil eructing.

Organic and Biofertilizer Differences

Although there is a significant difference between organic fertilizer and bio-fertilizer, the phrase "organic fertilizer" was formerly used to describe it. According to Vishal and Abhishek, Biofertilizers like fungus, algae, and bacteria are formed of microbial inoculants, which are live cells of microorganisms, and may be used alone or in combination to increase crop yield. Organic fertilizers may be obtained from either plant or animal sources, such as animal or green manure[4].

Biofertilizer Types

Depending on the microorganisms utilized, there are several kinds of Biofertilizers.

Utilizing Microorganisms to Create Biofertilizer

The elements of organisms utilized as Biofertilizers include K-solubilizes, N-fixers, P-mobilizers, and P-solubilizes, which are used alone or in conjunction with fungi. The majority of microorganisms participate in close proximity to the plant roots utilized as Biofertilizers. Due to their symbiotic relationship with legume roots, rhizobacteria restrict the growth of root surfaces or rhizosphere soil. The insoluble phosphorus produced by phospho-microorganisms, including fungus and bacteria, is available to plants. By using a few species of fungus and a large number of soil bacteria, it is possible to manufacture soluble forms of insoluble phosphate in soil by hiding biological acids that cause the breakdown of phosphate-bound systems and reduce soil pH. Azospirillum, Azotobacter, VAM, and PSB, for example, might be seen as broad-spectrum Biofertilizers, in contrast to Azolla, BGA, and rhizobia, which are bio-inoculants and crop-specific. Fungi known as VAM are often seen with enhanced plant nutrient uptake and agricultural crops. Azotobacter, facultative anaerobes, obligatory aerobes like Clostridium pasteurianum, certain methanogens, and the photosynthetic bacteria Rhodobacter are a few examples of free-living N-fixing microbes that are producing anaerobic conditions. The most common K-solubilize is Bacillus mucilaginous, while P-solubilizes include Bacillus circulans, Bacillus megaterium, Pseudomonas straita, and Bacillus subtilis[5].

Symbiotic N-Fixers: A Biofertilizer

The most accessible symbiotic nitrogen fixers include several genera of the family Rhizobiaceae, such as Azorhizobium, Allorhizobium, Mesorhizobium, Bradyrhizobium, Rhizobium, and Sinorhizobium. Rhizobium, a symbiotic bacterium, is found in conjunction with the root nodules of the host plants. Rhizobium fixes ambient N2 gas in the root nodules mostly by the conversion of molecular N2 to NH3 derivatives. The plants went on to use these fixed NH3 derivatives to make a range of proteins, vitamins, and substances that contain nitrogen. The process of N-fixation is carried out by the enzyme dinitrogenase, which also includes the multifunctional nitrogenase enzyme dinitrogenase reductase, which has iron as its cofactor.The nif genes, which control the nitrogen fixation process, are present in both symbiotic and free-living microorganisms. Rhizobium injection is a crucial agricultural preparation when nitrogen fertilizer isn't being used to verify a sufficient supply of N2 for legumes. Azolla has the potential to repair ambient N2 in comparison to the N2-fixing Anabaena azollae. Azolla serves as an alternate source of nitrogen for the industrial fertilizers that contain nitrogen.

Biofertilizers: N-Fixers That Live Freely

Azotobacter is a large free-living N-fixer of the Azotobacteriaceae family that often lives in neutral as well as alkaline soils. Azotobacter fixes ambient N2 in non-leguminous plants, primarily vegetables, rice, and cotton, without the need for a specific host or symbiotic relationship. Additionally, Azotobacter may grow and enhance grain harvest, particularly in wheat crops. Immunization against Pseudomonas and Azotobacter and artificial insemination decreased the field's use of chemical fertilizers by 25% to 50%. Azotobacter chroococcum, one of numerous groups of Azotobacter, is the dominant species found in arable soils and has the potential to fix between 2 and 18 mg/g of N2. The other Azotobacter species that are used for the fixation of atmospheric nitrogen include Azotobacter insignis, A. beijeri-nckii, A. vinelandii, and A. macrocytogenes. The various types of Azotobacter were found to be able to hide phytohormones, extra bioactive mixtures, and vitamin B complex in order to further increase mineral absorption, root development, and function as biocontrol agents against root infections. Additional substances, such as antifungal substances, are created by Azotobacter indicum and are used to stop the growth of several harmful microorganisms.

BGA, also known as cyanobacteria, are primarily photosynthetic nitrogen fixers that are free-living. The top four plants for fixing atmospheric nitrogen are Nostoc, Anabaena, Aulosira, and Calothrix. The excretion of numerous developments endorsing constituents on BGA increases the soil's capacity to hold water while also preventing the growth of undesirable plants, reducing soil salinity, and increasing soil productivity through the production of numerous organic acids.

Associative Symbiotic N-Fixers in Biofertilizers

Azospirillum is the most asso-ciative symbiotic nitrogen fixer, and it is mostly connected via various grasses. Currently, the Azospirillum thio-philum, Azospirillum zeae, Azospirillum picis, Azospirillum rugosum, Azospirillum melinis, Azospirillum oryzae, Azospirillum largimobile, Azospirillum lipoferum, Azospirillum humicireducens, Azospirillum irakense

There are 17 different species of Azospirillum, including A. brasiliense and A. canadense. Azospirillum brasilense and Azospirillum lipoferum are the two species that have been most thoroughly studied and characterized. These species have been iso-lated from the aerial portion of plants in addition to soil-participating potential to fix nitrogen. Azospirillum has generated cytokinins, gibberellins, and IAA, which are growth promoters. The findings indicated that Azospirillum might help plants survive in adverse conditions by influencing changes in osmotic adjustments and the flexibility of the cell wall. Azospirillum strains are advertised as biofertilizers in several countries, including Argentina, Africa, Belgium, Australia, Germany, Brazil, India, France, Mexico, Italy, Uruguay, Pakistan, and the United States [6].

Microorganisms that Solubilize Phosphorus

Among the active macronutrients, phosphorus plays a crucial role in the biological development of crops. Despite it's in height entire attention, its solvable concentration is little and inaccessible to plants. In soil, it may be found in both organic and inorganic forms. Therefore, the use of chemical fertilizers often causes inorganic P to be visible in the soil. Instead, biological material systems, which make about 20% to 80% of the soil, serve as a vital repository for immobilized P. The important reserves that are only marginally soluble and represent the mineral systems of the P in the soil are the hydrated oxides, such as manganese, aluminum, iron, apatite, and hydroxyapatite. PSM is known to support development plant components and has the capacity to transform the P system from an unsolved system to a solvable system. The several techniques that are intricately woven into this adaptation include chelation, exchange reactions, and acidity. The P-solubilizes' mechanism of releasing phosphorus from the soil involves the acid phytases and phosphatases significantly. The end effect is that PSM promotes the development of the plants, which serve as Biofertilizers, by producing a variety of phytohormones including IAA and even harvest siderophores[7], [8].

CONCLUSION

The use of PGP bacteria as bio pesticides and Biofertilizers has made significant progress in this field. The varied bacteria's partners are responsible for the health of the plant and the growth of the soil. Numerous microorganisms that function as Biofertilizers and bacteria that fix nitrogen have been included in this chapter. Many innovative techniques, such as the growth of microorganisms, gathering of these microorganisms, and extra suitable conveniences for distribution, applying, and framing these microorganisms for transferring from greenhouse and laboratory to field test will result in the first problem. The widespread use of these bacteria would therefore be essential to dispelling the widespread misconception that microbes are important disease mediators.

Before deploying these microbes to the environment on a wide basis, these misconceptions must be dispelled. Several chemical pesticides are used to control pathogenic illnesses, however doing so results in crop loss, renders crops unsuitable, and has ecological consequences. Therefore, solving these issues is crucial. Biofertilizers will serve as a potential alternative for feeding the growing population and will improve plant growth and increase productivity. By using Biofertilizers, we may progress agricultural practices by making the accumulation of these fertilizers affordable, simple to complete, and biodegradable. The many nitrogen-fixing microorganisms and other alternatives for the simple production of Biofertilizers are also included in this chapter. This research will assist the reader in selecting the appropriate microorganisms and bio-fertilizer to achieve a high yield in agricultural settings.

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CHAPTER 4

BIOFERTILIZERS IN ORGANIC AGRICULTURE

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ABSTRACT:

One of the greatest, simplest, and most affordable components of contemporary fertilizers is Biofertilizer. It is a gift to our agricultural science in the modern period. The usage of Biofertilizer in India's agricultural sector dates back to ancient times, and it continues to be very effective as a substitute for regular fertilizers today. Traditional fertilizers include green manure, dung, and household trash. These fertilizers have a less impact than chemical fertilizers, meaning that they have a smaller environmental impact. Farmers so often attempt to utilize these chemical fertilizers in their crops, taking into account the objective of crop growth. Because the chemical fertilizers we use have a negative impact on our environment and endanger the life there. These fertilizers are mostly to blame for the degradation of the soil, water, and air as well as the development of deadly illnesses like cancer. In addition, over time, chemical fertilizers may slowly erode the agricultural soil's fertility. We now only have one choice: Biofertilizer, which has shown to be effective in addressing the issues raised and fostering a healthy environment. Since Biofertilizer includes microorganisms that provide the vegetative world the nourishment and optimal growth as well as development in physiology and regulation. These fertilizers are made possible by the collaboration of live microorganisms. Only those microbes that specifically contribute to improving the flora's reproduction and sustainable growth are introduced in this response. Bio-fertilizers are an integral part of organic farming and are crucial for enhancing soil fertility and stability, lowering environmental impact, and preserving life on Earth through preserving the ecosystem.

KEYWORDS:

Biofertilizer, Cyanobacterial, Mycorrhiza Vermicomposting, Organic Farming, Weed Management.

INTRODUCTION

An organism known as a Biofertilizer is one that improves the soil's nutrient content. The primary sources of bacteria, fungus, and cyanobacteria are those mentioned. The symbiotic relationship between Rhizobium and dicotyledonous plants results in the formation of glands at the roots. These bacteria make organic nitrogen from atmospheric nitrogen, which plants may utilize as nutrition. In the soil are other bacteria like Azospirillum and Azotobacter. Additionally, it can maintain atmospheric nitrogen. As a result, the soil's nitrogen concentration rises. People have long been aware that pulses boost the soil's fertility. But it took till the second half of the 19th century for this to be proven scientifically. In the roots of plants belonging to the Dahlan clan, knees are generated for the fixation of nitrogen. The Mimosidi, Sijalpinidi, and Papilionidi subscales make up the pulses clan. 90% of the mimosidi, 23% of the cajalpinidi, and 97% of the papillonidi have roots with knees for nitrogen fixation[1].

The nitrogenous product originated as a Rhizobium culture in partnership with two scientists, "Mr. Knob and Mr. Hiltner," and this is when the commercial history of biofertilizers began. The discovery of Azotobacter, Indigo Green Algae, and other microbes came afterwards. Recent discoveries include Azospirillum and Vesicular Arbuscular Mycorrhiza. Dr. NV Joshi, an Indian scientist, investigated the first Rhizobium symbiosis in a bean in India. In 1956, the first commercial manufacturing began. With the "National Project for the Use and Development of Biofertilizer," part of the government of India's ninth five-year plan, the ministry of agriculture began to actively promote it and raise public knowledge. Plants develop symbiotic associations with amiable fungus. The genus Glomus contains several mycorrhiza-producing plants. Fungi extract phosphorus from the soil in this symbiotic relationship. The plants, then deliver it to them. These interactions result in tactile plants that have a variety of additional advantages, including resistance to diseases that infect the roots, salt tolerance, drought tolerance, and growth and development. The rising usage of chemical fertilizers in agricultural is linked to several issues. As a consequence, organic farming and the usage of Biofertilizers are being prioritized.

Biofertilizers in Organic Agriculture

Indian farmers are employing them in their crops since they have lately begun in India. Compared to chemical fertilizers, its usage has decreased the need for nutrient replenishment and dependency on the local agricultural area. Chemical fertilizers are used to improve agricultural output, but their continual use degrades soil fertility and structure, therefore using both chemical and biological fertilizers increases the fertility of productive land. Utilizing Biofertilizers increases output by supplying nutrients and dirt to the soil. Farmers have begun utilizing deadly pesticides and artificial fertilizers to grow their crops, endangering both human health and the earth.

The environment is likewise becoming more contaminated at the same time. If the farmer employs organic techniques rather than chemical ones to stop all of these things, then these issues may be greatly reduced.

Biofertilizers

The most important nutrients for every crop are nitrogen, potassium, and phosphorus. If plants or crops lack these nutrients, fertilizer may be used to make up the difference. The ecology of the location where this fertilizer is utilized is negatively impacted if it is a chemical substance. The usage of bio-fertilizers may lessen the need for these dangerous chemical fertilizers. Biofertilizers are fertilizers that rely on microorganisms to provide nutrients to plants or crops via a variety of chemical processes; this kind of farming is known as organic farming. Due to its versatility Biofertilizer has proven valuable in transdisciplinary sectors.

Biofertilizer, sometimes known as "bacterial fertilizer," is a sort of microbe containing living fertilizer that has been discovered by researchers and utilized for the cultivation of sustainable crops. By using chemical fertilizers as a supplement, Biofertilizers may provide superior results. Biofertilizers really combine certain microorganisms with any moisture-bearing materials. By combining certain numbers of unique microorganisms with a wet, powdery material, Biofertilizers are created. It is often offered on the market under the heading of "culture." Biofertilizer is really a natural product. They may be utilized for a variety of crops and as a partial sulfur source. They enhance the physical and biological qualities of the land and aid in boosting its fertility instead of having any negative effects on it. The use of Biofertilizers is crucial in organic farming. Bacterial manure has a slow impact[2].

DISCUSSION

The advantages of Biofertilizers

These are the primary advantages of using Biofertilizers:

1. Organic fertilizers are easy to make and may be created for a minimal price.
2. Their usage boosts the effectiveness of soil fertilizer and encourages the development of sustainable agriculture.
3. Biofertilizers are used to improve the soil's physical and chemical characteristics as well as its capacity to retain water, hence improving the fertility of bearing land as well.
4. Use of bacteria like Rhizobium, Azotobacter, and Azospirillum may deplete the nitrogen in the soil.
5. Cyanobacteria secrete protein, amino acids, vitamins, and stabilized dinitrogen, which helps to enhance the quantity of organic material in the soil.
6. The surface area of the roots is increased by using mycorrhiza Biofertilizer. For phosphate feeding in plants, VAM is crucial. The ability of the earth to absorb water and mineral salts improves, which leads to an increase in production.
7. Natural resources are used to make Biofertilizers. They do not contaminate the environment as a result of being environmentally friendly [3].

Application Method for Biofertilizers

Living microorganisms create Biofertilizer. Because of this, care should be taken while using them to prevent harm to bacteria. There are typically four ways to use them.

Treatment of Seeds

Depending on the size of the crops being slowed by the seed, different amounts of Biofertilizer are utilized. The treatment of 10-15 kg of medium-sized seeds, which may produce a 400–500 ml solution in a glass of water, typically requires 200 g of Biofertilizer. The solution should then be added to 10–12 kg of seeds, which should then be well mixed by hand and placed in a shaded area on clean paper or sacks to dry briefly.

Treating the seedling

For sowing, transplanting crop is employed. They instantly plant the roots of their young plants after immersing them for 10 to 15 minutes in a Biofertilizer solution. In a sizable container, combine 1-2 kg of Biofertilizer with 5–10 L of water to create the solution[4].

Treatment with Setts and Tuta

Sugarcane and crops like potatoes are both grown using this strategy. Typically, 20–40 L of water are used to make 2-4 kilogram of Biofertilizer solution for an acre of land. Selts or tubers are treated by submerging them in this solution for ten to fifteen minutes, or by filtering and misting this solution over them.

Soil Care

For short-lived crops, 60–100 kg of the same field soil or local manure are combined with 3-5 kg of Biofertilizer. The crop is irrigated the next day after being sprayed with water during the night. The aforementioned procedure is used for soil treatment when it comes to crops that need to be treated for an extended period of time. Just take 100–120 kg of soil or desi fertilizer and 6-7 kg of Biofertilizer.

Applications in Industry

The Bacterium Rhizobium culture is now grown for commercial purposes in the current day. Yeast extract serves as the culture's medium. In the US and other nations, Rhizobium Meliloti and Rhizobium are utilized as bacterial manure. These bacteria are mostly cultured on yeast extract mannitol medium. Bacteria also employ yeast extract mannitol as a growth medium in India. This medium should be shaken for many hours in big flasks before being treated with $CaCO3$ and autoclaved by inserting cotton plugs into the flasks. Let the medium cool after that before adding the broth. It is then dried in a tray after this. They are then handed to the farmers after being packed in plastic bags. Azotobacter chroococum and Bacillus megatherium are cultivated on other medium as well. These bacteria also produce commercial-grade manure in India.

Biofertilizers made of Cyanobacteria

The ability of blue-green algae or cyanobacteria to fix nitrogen is unparalleled. According to their research, it is evident that some heterocyst-holding filamentous cyanobacteria, including oloceira, tolypothrix, anabaena, cylindrospermum nostoc, and mastigocladus, fix nitrogen in rice fields. These consist of nitrogen when the nitrogenase enzyme is present. It has been noted that as these creatures pass away, their bodies release ammonia, which nitrifying bacteria then convert into nitrates, or $NO3$. It has been established via a number of significant studies on the blue-green algae Tolypothrix in Japan and Aulosira Fertillissima in India that 30 quintals of rice can be cultivated by cultivating these algae in paddy fields with high percentage yields. Spirulina and Phalaenopsis are also utilized as fertilizers in India. Antibiotics produced by Lyngbya and other cyanobacteria kill Pseudomonas and Mycobacterium. In addition, some members are utilized as a larvicide since they have the ability to kill mosquito larvae[5], [6].

Applications in Industry

Blue-green bacteria like Anabena, Tolypothrix, Aulosira, Nostoc, and Plectonema are cultivated in a commercial facility today.

Biofertilizers in Organic Agriculture

This is utilized as a Biofertilizer in labs. The 9 inches long, 6 inches wide, and 3 inches deep tray is used for preparing culture. The algae that are to be grown are stored in a tray with clean soil, which is filled to a depth of 2 to 2.5 inches with 10 kg of soil and 200 g of superphosphate. When you add an inch of water, the dirt sinks to the bottom. After that, keep the tray with the water poured in it in the sun after sprinkling it with sawdust. Blue-green bacteria start to develop and float on the water's top after a week or two. They are meticulously gathered, placed in plastic bags, and sent to the marketplaces. Where farmers may purchase them to use as field fertilizer. This fertilizer is really affordable. One hectare of land may be fertilized with 30 rupees worth, according to estimates. In open tanks, productive strains of cyanobacteria are cultivated by choosing productive strains. Molybdenum and phosphate, two water-filled mineral components, are supplied in large quantities to the tanks.

After that, cyanobacteria development is permitted before the water's surface is removed, dried in the sun, ground up, and combined with the carrier. When the farmers get this combination, it is packaged in polythene bags. The bags are unzipped, and the mixture, which serves as fertilizer, is scattered across the farmed land. Other crops gain from cyanobacteria leftovers, and it has been shown that the application of cyanobacteria to rice fields does not need nitrogen fertilizers. Heterocyst rice production rises in cyanobacteria by 10% to 30%.

The amount of nitrogen that can be supplied with cyanobacteria fertilizer is estimated to be 25 kilogram per acre.

Factors Affecting Biofertilizer Made of Cyanobacteria

Biofertilizers using Mycorrhiza

Mycorrhiza, according to Frenk, denotes derivation from fungi. High-grade plants like Monotropa and Neotia, which live out their lives like dead animals, contain numerous fungus in their roots that aid in the absorption of organic materials. There is no special connection between fungi and plant roots. Fungi of the same species or several species of the same species might be found on the roots of a single plant. The kinds of mycorrhizas include the following[7].

Ectotrophic Fungi

In this, the surface of the root of the nutrient-rich plant develops a coating or mantle of fungal hyphae. The nutritive plants that grow on a plant's root's epidermis penetrate the hyphae and create a net. The majority of the fungal fibers that are dispersed over the surface of the root enter the soil that contains organic matter, which is made soluble by the production of certain enzymes and absorbs them.

In this manner, the absorbed organic material gets to the plant-feeding fungi found in the root cells. The epithelium of the roots of such plants lacks root follicles. Examples may be found in birch in beech or betulaceae, oak in phagaceae, and coniferous pines. There are certain plants, including Monotropa and Sarcodes that are only present in the roots of Saprophyte Mycorrhiza. The layer of fungi that surrounds their roots entirely absorbs all the nutrients that the plants need. Chlorophyll is absent from these plants. Numerous forest trees, including Salix, Eucalyptus, Cedrus Deodara, Picea, and Popix, have roots produced by ectotrophic mycorrhiza. Both the morphology and the development of the root hairs alter. Because plants with mycorrhiza have a greater capacity to absorb mineral salts, the interaction between nutrients and fungus is particularly advantageous in this manner.

Mycorrhizae Endotrophic

In this kind, the fungus spreads throughout the surface of the root rather than forming a coating on the root of the nutrient-rich plant. A several of them are fungi

Biofertilizers in Organic Agriculture

Fibers infiltrate the soil, and certain fungus live in the gaps between the cortex cells of the root's cortex where they have made a deep inroad. Sugars and vitamins are obtained by fungi from the host plant. Fungi don't hurt the plant in any way. This fungus supplies nutrients to the plant like the tuber of a green orchid by absorbing organic components, minerals, and nitrogenous compounds from the soil with the aid of hyphae. Experiments have shown that if the nutritive plant and the fungus found inside it are cultivated independently, the development of both is significantly slowed down.

In this way, the nutritious plant provides fungus with sweet vitamins and amino acids. The fungus aids in expanding the roots' surface area for absorption and aids in the plant's ability to accumulate nutritional units. It has been noted that green orchid seeds do not germinate effectively until they are infected with fungi; it is assumed that the young seedlings are infected with fungi. They take in nutrients like potassium, phosphorus, and nitrogen, but after the plants are fully grown, they serve no significant use. Additionally, these fungus produce useful auxins. Fertilizer applied to fields soon begins to nitrify; however, it is not nitrified when being kept in a dung heap. There is little oxygen and a high organic content in hemorrhoids. Nitrification is thus not feasible[8].

Mineral Compound Changes

Carbonic phosphorus, which is unavailable to plants and often transforms into inorganic phosphorus, makes up the majority of the phosphorus in cow dung or shit matter. Most potassium is present in urine, and it may be readily discovered as salts or in a soluble form. A portion of the potassium is transformed into potassium carbonate, which balances the acids that are created when carbs are broken down. After being dissolved, the salts of insoluble calcium, magnesium, and potassium are changed into soluble forms, where they are then ingested by plants.

Organic Agriculture

Organic farming refers to a type of agricultural production that makes little to no use of chemical pesticides and fertilizers. Its primary goal is to boost agricultural yield while maintaining the fertility of the soil.

Goals of Organic Agriculture

The primary purposes of organic farming are to protect soil fertilizer from usage and to avoid using chemicals in food, which are consumed indirectly on a daily basis. Supplying crops with these nutrients, which are efficient against microbes yet insoluble in soil and crops. Utilizing organic manure, organic nitrogen, and recycled organic resources. Avoiding the use of drugs to kill the kit, weed-sprinkling, and crop-disease-causing agents in order to protect people's health. In organic farming, care is taken of both the crops and the animals, including their environment, upkeep, and feeding. The conservation of the environment, wild animals, and other forms of natural life are the two main goals of organic farming.

Advantages of Organic Agriculture

The farmer is the most crucial element in farming, followed by the farmer's land and the adoption of organic farming, all of which are quite advantageous. By switching to organic farming, the ground becomes more fertile and the irrigation gap for crops is widened. The cost of planting for the farmer's crop is also minimal if he employs organic manure instead of artificial fertilizers. The farmer's agricultural production rises, which also improves his profit. The quality of the soil is also enhanced by the usage of organic manure. With the employment of this technique, the ability of the soil to retain water rises and water evaporation is reduced. These days, our environment is also getting highly polluted, and using organic agricultural practices is also very beneficial to our ecosystem.

Environmental Benefit

By refraining from using chemical compounds, the land's water level rises and the pollution brought on by the soil, food, and water in the land is decreased. Making manure from animal waste and dung lowers pollution, which in turn lowers mosquito populations and other muck that spreads illness. There is a significant demand for the goods generated by organic farming on the global market as well. Crop output rises as a result of organic farming, boosting farmers' revenue. It is crucial that farmers in agricultural nations like India utilize organic farming practices to maximize crop yield. This issue will be resolved, and the farmers' physical condition will also advance. The majority of Indian agriculture depends on rainfall, yet these days, rainfall is not occurring when it should, leaving agricultural land unusable. Farmers may potentially solve this issue by switching to organic farming[9].

How to Farm Organically

Organic farming is largely a blend of ecological, contemporary technological, and traditional agricultural expertise. In the subject of agroecology, we may investigate the practices of organic farming. Farmers may utilize water and synthetic pesticides while using the conventional agricultural approach. In contrast to organic farming, which discourages the use of natural pesticides and fertilizers, it employs soluble chemical fertilizers. Crop rotation, organic manure, biological kit control, mechanical farming, etc. are the major techniques used by farmers that practice organic farming. These techniques also rely on using natural resources, such as soil nitrogen levels, to boost agricultural yield. Fruit planting, encouraging natural insect predators, crop rotation, and other measures are used to address this.

Methods for Organic Agriculture

No matter how far a nation advances, it doesn't matter. Agriculture has always provided man with a means to satisfy his fundamental necessities, including food, as well as a means of livelihood. The agricultural business has faced challenges in order to satisfy the expanding demand as a result of the population's dramatic growth, and many technologies have been used to address these challenges. In organic farming, a lot of innovative technologies are being developed to harvest and harvest the greatest quality crops.

The benefits of Organic Farming

An agricultural practice known as "organic farming" forgoes the use of artificial fertilizers, pesticides, growth regulators, and other food additives. The production of crops, plant leftovers, animal manures, leguminous plants, green manures, farm organic wastes and biofertilizers, mechanized farming, and mineral-supplying rocks are all essential components of organic agriculture. Plants must manage nutrients, biological pests, weeds, pests, and other pests in order to sustain soil production. It is possible to access all agricultural goods, including cereals, meat, milk, eggs, and fibers like cotton and jute. In this manner, bio-agriculture contributes to the development of a sustainable way of life for future generations.

By correctly caring for the soil's living elements of which the field's microorganisms are a vital part since they aid in the transformation and transport of nutrients bio-agriculture creates healthy soil. By using this approach, the land's composition is strengthened and its capacity to retain water is increased. With the use of certain crops, fertilizers, and organic matter, these farmers keep the soil fertile. With the help of this technique, strong plants are grown that are resistant to insects and pests.

The primary goal of bio-farmers is to keep pests and illnesses at bay by providing healthy food and care for their plants. Intelligent use of cover crops and plant cycling by bio-farmers alters the farm's ecology and eliminates weeds, pests, and disease-causing organisms from their habitat. Transmission techniques used to control weeds include crop rotation, technical plowing, manual weeding, and covering crops with mulch, burning weeds, and other management techniques.

These bio-farmers utilize soil-based bacteria that are advantageous to insects and birds to manage the germs that harm plants.

Bio-farmers depend on birds to monitor the diversity of soil organisms, the amount of pest insects, and other helpful insects. Farmers safeguard crops employing a variety of techniques when the use of pesticides is greatly increased, including deploying nets, inhibitors, and birds to hunt out pests. We go into great length about the following benefits of organic farming.

To Maintain Nutrients

The amount of nutrients in the cereal grains and vegetables produced decreased as the quantity of chemical fertilizers rose. The situation now is such that more hazardous substances have been created from nutrients in numerous vegetables and cereals, including brinjal. The use of food derived from crops grown with the use of harmful chemical fertilizers and pesticides is causing a wide range of illnesses to develop among the populace. It is difficult for the average person to have them treated. Therefore, the nutrients in the food grains will not be preserved if conventional farming is not replaced with organic farming.

To Lower Agriculture Costs

Pesticides and chemical substances of every kind are utilized in conventional agriculture. In order to prepare a crop, farmers must invest a lot of money. Organic farming will be practiced, but it won't be as expensive. Compost is created from all the trash litter and garbage, including cow manure, which costs less than other forms of pricey chemical fertilizers.

To prevent the use of dangerous substances in Animal Products

In reality, the farmer uses a significant portion of the produce he raises as animal feed. Animals who consume those four give birth to a variety of hazardous substances inside of them. Humans then consume items such as milk, meat, and eggs that were produced by the same animals. These substances enter a man's body via milk and eggs. They are the root of several illnesses. More than 90% of the chemical components that enter the human body, according to US-published research, solely come from milk and meat.

To safeguard the Natural World

Spraying of pesticides of various kinds has a negative impact on the ecosystem. Pesticides are sprayed by farmers, and it's reported that more than 90% of it gets Less than 10% of the crop is planted; the rest is thrown into the air. In this manner, the environment becomes more polluted when the 90% component is mixed with air. On those who reside there, there is a tremendous impact. Therefore, practicing organic farming will aid in maintaining a clean atmosphere.

Organic and Palatable

People who have eaten food from organic farming never forget its flavor since the fruits and vegetables have better flavor. One thing that is important to note is that organic farmers usually focus on quality rather than quantity.

CONCLUSION

Biofertilizers are nutrients for plants that are obtained from creatures like bacteria, fungus, and algae and have no negative impact on the environment or the soil. Artificial inorganic fertilizers, herbicides, growth regulators, and animal feeds are not used in an organic agricultural system. Foods produced using the organic farming method are devoid of dangerous chemicals as well as artificial flavors and preservatives. In addition to protective plants to preserve soil vapor levels, a sustainable farming system includes crop rotation, polyculture, and suitable soil management techniques. Vermicomposting is a system in which leftover waste is fertilized in an efficient way that benefits both the environment and agricultural output. This process is so straightforward that it may be carried out in a park or even in a corner of your garden or school grounds. By providing us with the fruits of various forms of organic agriculture, they are nourishing us. By improving productivity, reducing environmental pollution, eliminating pesticide side effects, and saving money, it has proven effective in a variety of ways. We should support the new technology that makes it possible to manufacture Biofertilizers in accordance with the crops and their crop cycles. Chemical reactions involving fertilizers are largely influenced by the environment. According to the earth's other nitrates, phosphates, calcium, and molybdenum levels, which aid in rhizobial protein synthesis and alkalinity, salinity, and agricultural soil acidity, all of which affect all reactions, the ability of the earth to retain water using Biofertilizers reaches the pinnacle of development alongside the farmer.

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CHAPTER 5

ORGANISMS THAT SOLUBILIZE PHOSPHORUS

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ABSTRACT:

The poisoning of the chemosphere and biosphere by phosphorus has escalated into a significant environmental problem. The broad and unintentional use of chemical fertilizers and animal feeds containing phosphorus in agricultural and farming operations may be regarded as the primary cause of this contamination. On the other hand, all species need external phosphorus supply since it is a crucial component of our environment. However, the majority of the phosphorus in the soil or in the water cannot be absorbed by organisms, particularly plants, thus it must be changed into soluble forms. Numerous microorganisms have the ability to convert phosphate from both organic and inorganic sources into soluble phosphate, which replenishes the rhizosphere with enough phosphorus. These phosphorus-solubilizing microorganisms hold promise as efficient biological solutions to the phosphate pollution of the environment and the dirty feces of animal farms. They may be added to the soil, sprouts, and seeds as a part of the rhizosphere to provide the crops with useable phosphorus. This chapter provides a concise summary of the literature on phosphate pollution, phosphate-solubilizing microbial species, and their enzymes. Additionally, the function of these bacteria in plant development, agricultural application techniques, and elements influencing microbial survival are discussed.

KEYWORDS:

Agricultural Plant, Arbuscular Mycorrhizal Fungi, Enzymes, Inert Phosphate, Pollution, Solubilization.

INTRODUCTION

Phosphorus is a crucial chemical element necessary for the production of fuels and nutrients and is a non-renewable geological resource. It is essential to all life forms because it controls the fundamental cellular energy cycles that enable functioning cellular systems. Since phosphorus is one of the most crucial nutrients for photosynthesis-sis, farmers regularly add it to the soil to boost crop production. It also helps to lessen the risks brought on by soil contamination with metals because soluble metals can precipitate as poorly soluble phosphate minerals in contaminated soils, which can greatly reduce bioavailability. In the form of mineral and organic phosphorus, various phosphate compounds are cycling between the rocks, water sources, soils, sediments, and living organisms. Phosphate ions and other minerals are released from rocks over time by weathering and precipitation. Inorganic phosphate that has been released can be diluted in soils and water and absorbed by plants. Animals' consumption of plants also results in the transport of phosphate to other organisms. Phosphate is a component of bio-organic molecules found in plants and animals such as DNA. When an organism dies or degrades, organic phosphate is eventually returned to the soil[1].

Between the lithosphere, hydrosphere, and biosphere of the earth, phosphorus is constantly moving. Phosphate rock in the lithosphere is a good source of phosphorus, but it cannot be extracted from the biosphere or the hydrosphere. Typically, phosphate rock is used as a raw material to create phosphate fertilizer.Due to the low cost of phosphate fertilizers, phosphate pollution is growing in the food and crop production as well as waste management chains. Urban wastewater originating from fertilizer flow and sewage from agricultural areas are two of the main contributors to phosphate pollution. Despite the fact that phosphorus is typically considered to be a limiting nutrient for freshwater habitats, its concentrations in wastewater systems may be higher than what algae and macrophytes can metabolize, which can result in phosphate toxicity. The excessive phosphorus buildup in the soil and eutrophication brought on by intensive animal farming raise environmental concerns. The enrichment of aqueous environments with different organic compounds is what is known as eutrophication. It is one of the most prevalent inland water environmental issues and needs to be resolved immediately in developing nations, especially to protect water resources. For a number of reasons, the quality of water from dispersed food sources degrades. First off, agricultural output is frequently outpaced by the phosphorus inputs from commercial fertilizer and animal feed supplements.

Second, an overabundance of animals can increase fertilizer production, which is greater than the capacity of the soil to hold it and the needs of nearby crops. In many cases, over-fertilizing the soil encourages phosphate leakage into ecosystems of moving and downstream waters. Such an overabundance of phosphorus in the soil can persist for a millennium, encourage the buildup of phosphate in lakes downstream, and alter the mechanisms that control lake structure and function. Before the 1990s, point and non-point discharge of phosphorus-rich wastewater was primarily blamed for the formation of eutrophication. A delay in recovery has been observed for many lakes after the reduction of the external phosphorus load, despite the fact that measures to address the eutrophication problem focus on reducing external resources. Therefore, it is believed that the primary process causing this delay is the release of phosphorus from sediments. Studies on lakes in Europe and North America indicate that this process typically lasts 10-15 years after external phosphate reduction. The release of phosphate from sediments can contribute to most of total phosphate input in some lakes, and becomes the main driving force of primary production, especially when bottom waters become anoxic in the summertime[2].

Solubilization of Phosphorus

The soil has always been a volatile environment and is a biological resource of intense microbial life, which is primarily influenced by its maternal matter’s molecular structure and the activity of the organism it maintains. Phosphorus required for intracellular needs relies on the average amount of phosphate in the field as well as on its solubility, which is ascertained through various natural transformations and biochemical reactions. Ground phosphate is generally categorized as organic and inorganic phosphorus. The reactions of fixation and immobilization taking place in the ground convert phosphate toward variants that are not beneficial for crop activity it is worth recalling that large amounts of the administered phosphate fertilizers are settled in the land, making it unusable for seed intake. Phosphorus can be found as inorganic phosphorus produced by the decomposition of the bedrock or as organophosphate acquired from rotting plants, animals, or microbes. Primary crystals including apatite, hydroxyapatite, and ox apatite signify the elemental sources of phosphate. The insolubility is the principal fundamental characteristic of the above crystal varieties. These can, however, be kept solubilized and serviceable to microbes and plants within certain scenarios. The phosphate is an indispensable part of the living organism’s metabolic tasks. It has an established function in a variety of cellular events including hereditary trait transmission and metabolic pathway management[3].

DISCUSSION

Microbial Mechanisms of Phosphate Solubilization

Worldwide phosphate fertilizer yield is around 10%–25% and the bioavailable phosphorus concentration reaches one milligram per kilogram of soil. Different types of microbes assist the plant growth by turning phosphate from inert form to plant-usable form. They are promising as the best environmentally friendly option to provide plants with cheap phosphorus. Microbial phosphate solubilization mechanisms are largely varied in nature, and much of the earthly cycle of inert organic and inorganic soil phosphates is assigned to bacteria and fungi. However, it has been suggested that bacteria are predominant and more effective than fungi in this process. The main processes used by micro-organisms for soil phosphorus solubility can be summarized as secretion of mineral solvent compounds, enzyme-mediated biochemical phosphate mineralization, and phosphate assimilation by releasing phosphorus from more complex substrates[4].

Organic Phosphate Solubilization

Depending on soil characteristics organic phosphate can make up 4%–90% of total soil phosphorus content. Organic phosphate solubilization also called phosphate mineralization has an imperative character in the phosphate availability of the horticulture. Organic phosphorus com-pounds cannot be directly used by the plant; therefore, they need to be converted to mineral form by enzymes. These compounds are easily mineralized as they are accessible for microbes and their enzymes and mineralization mainly depends on their chemical nature. This process occurs by the action of bacterial enzymes such as non-specific acid phosphatases, phytases, lyases, and phosphonatases cleaving carbon-phosphate bonds. By hydrolysis of ester bonds in high molecular weight organic phosphate, phosphatases cause the discharge of phosphate ions. According to their optimum pH, they are categorized as acidic, neutral and alkaline phosphatase enzymes they are secreted by both microorganisms and plant roots. However, it is very difficult to distinguish phosphatases according to production sources. The phytases decompose phytate or my inositol phosphate substances.

As the biggest supply of inositol, phytate is the main component of phosphorus accumulated in rhizomes and spores and is also a key soil constituent of organic phosphorus. The main element in con-trolling soil phytate mineralization is microbial species. Although the plants' ability to acquire phosphorus from the phytate is exceptionally restricted, the perimeter of the microorganisms in the rhizosphere offers plants the opportunity to extract phosphorus directly from the phytate Phosphonatases and lyases cause enzymatic hydrolysis of the ester links in phosphoenolpyruvate and phosphonoacetate and turn them into phosphorus ions and hydrocarbons for intake[5], [6]. The availability of organic phosphate compounds can be a limitation for plant nutrition. Since phosphorus is highly reactive, it may interact with other metallic elements in the rhizosphere region and become unusable for plants delaying their growth as well as crop yields. Therefore, the ability of bacterial enzymes to perform the desired function in the rhizosphere is a very important consideration for plant nutrition.

Inorganic Phosphate Solubilization

The competence of organic microbial acids to dissolve inert phosphorus depends on the acidity level of the environment. Indeed, a decrease in ph. Phosphate-Dissolving microbes has been reported because of organic acids synthesized during the development of phosphorus solubilizing microbes in a culture environment. The delivery of organic acids through direct oxidation occurring on microbial membranes decreases the medium ph. Organic acids produced from phosphate-solubilizing bacteria include gluconic, formic, 2-ketogluconic, citric, oxalic, lactic, isovaleric, succinic, glycolic, and acetic acids. Organic acids responsible for phosphate solubility are fermentation products of organic carbon sources or microbial metabolic products of oxidative phosphorylation. There was a clear positive association between the production of organic acid and the index of phosphate solubilization. When inorganic phosphate is applied to the soil, it interacts with other metal ions, making phosphorus unusable for crops by the generation and release of insoluble salts such as calcium, iron, and aluminum phosphates. Organic acids produced by micro-organisms initiate chelation reaction, and phosphorus is separated from the metal part and becomes available for plant uptake. The chelating nature of hydroxyl and carboxylic functional side chains in these acids make the release of phosphate-bound metals, thus converting phosphorus into soluble forms. Being powerful chelating agents of iron, calcium, and aluminum ions, humic, 2-keto-gluconic, and fulvic acids are efficient in the solubilization of inorganic phosphate from any of these metal substances. Microorganisms liberate humic and fulvic acids during the degradation of plant matter. The variety of organic acids produced by different phosphate-solubilizing bacteria[7], [8].

In addition to organic acids, inorganic acids such as hydrochloric acid, sulfuric acid, nitric acid, and carbonic acid are also known to be effective in phosphate solubility. Even so, the input of synthetic acid to the liberation orthophosphates remains to be less effective than that of natural acid. Synthetic acids are released by nitrification and sulfur-oxidizing bacteria during the fermentation of nitrogenous or inorganic sulfur residues. Moreover, the reaction between hydrogen sulfide and iron phosphate causes the formation of iron sulfate and phosphorus is released at the same time. Thus, the generation of hydrogen sulfide is considered as one of the phosphate Solubilization mechanisms. Given the role of phosphorus in plant growth and development, phosphate-solubilizing bacteria is likely to be used as an effective Biofertilizer to improve the overall performance of crops, especially in areas with phosphate deficiency. Due to the environmental hazards and increasing costs of chemical fertilizers, the use of these bacteria in sustainable agricultural practices can be advantageous.

The Consortium of Bacteria and Fungi for Phosphate Solubilization

Inoculating numerous species that stimulate plant development utilizing a variety of processes is one of the alternative methods to boost productivity in phosphate solubilization. Studies on the synergistic impact of the bacteria-fungi consortium are developing in this setting. This consortium showed improved performance, particularly in nutrient-deficient soils. Additionally, they are combined in several additional applications to improve phytoremediation, reduce the use of chemical composts, and increase fruit quality and output[9]–[11].

Researchers are interested in the cooperative group of phosphate-solubilizing bacteria and fungus, as shown in Table 5.4. Unfortunately, there has been much too much conjecture about this synergistic impact. Co-inoculation, however, has shown out to be more productive for plant development than individual inoculation. Fungi extract the insoluble phosphorus from the soil and convert it to the soluble form in order to create this synergistic effect. While bacteria are believed to make the phosphorus that plants receive more usable for them

CONCLUSION

Since the phosphate that is now present in the environment cannot be broken down for use by high eukaryotes, phosphorus pollution is one of the most significant environmental concerns.

According to recent scientific and technological advancements, the most effective and most likely the only environmentally benign method to use in agricultural and land preservation procedures is the solubilization of phosphorus using effective microbial species and/or their enzymes.

The optimal use of these croplands is also a challenge facing our ecology, given the drastic decline in presently accessible and cultivable area. A possible strategy is to use these bacteria and/or fungi as biological fertilizers, however finding new microorganisms, genes, proteins/enzymes, metabolites, and cell-surface chemicals with high performance through bioprospecting is essential. High-throughput bioengineering research may also open up new avenues and improve the success of field applications. Based on the knowledge gained from bioprospecting investigations, recombinant strains with high-solubilization capacity functioning under certain safe and established conditions should also be produced.

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CHAPTER 6

PLANT-MICROBE INTERACTIONS: EXOPHYTIC AND ENDOPHYTIC RELATIONS

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ABSTRACT:

Since the beginning of time, associations have existed between living things. In order to coexist and compete for resources necessary for life, living organisms have had to develop new strategies. According to what is known in many scientific circles and beyond, these relationships eventually lead to evolution and life. Some of these relationships between living things, including both plants and microorganisms, are known as plant-microbe interactions. While some of these connections have shown to be beneficial to both symbiotic organisms, others are entirely parasitic, with one creature only benefitting at the cost of the other. When one creature just uses another as a habit without taking anything or adding to the process, the relationship does not always benefit or hurt the other species. Some of the biggest discoveries made by humans, mostly in the agricultural field, have been a result of the relationships between plants and microbes. In order to create chemicals that enhance plant health, these biological processes are copied. This includes the manipulation of microbial biochemical processes to increase crop yields by creating Biofertilizers and bio pesticides. This chapter will go through these interactions between plants and microbes, including how they work, how they affect the microbes and plants involved, and how they might be used to biotechnology and agriculture.

KEYWORDS:

Bioremediation, Biofertilizers, Plant-Microbe Interactions, Pathogenic Microbes.

INTRODUCTION

Interactions between microorganisms and plants are known as plant-microbe interactions. These interactions between bacteria and plants might have beneficial or detrimental impacts depending on who is involved. From the time the seeds germinate until the time the plant dies, bacteria are involved in the life of the plant. Microbial interactions with plants may occur either via the root or shoot systems. Microbes may interact either endophytic ally, growing within the plant, or epiphytically, growing on the surface of the plant, such as on the reproductive system or other exterior plant organs, such as leaves, roots, and stems. The majority of microbial activity takes place in the rhizosphere, a region that includes the soil and soil-dwelling organisms as well as the roots of the plant host. According to estimates, the microbial densities in the rhizosphere are 100 times greater than those found in topsoil. The rhizosphere's microbiome is significantly influenced by the surrounding environment, ecological variety, the plant host, and its root exudates.

Plants directly or indirectly support all living forms on earth because of their autotropic nature. Producers in the food chain are autotrophic organisms that manufacture their own nutrients and energy via a process known as photosynthesis. They engage in interactions with the surrounding invertebrate herbivores, microbes, and plants. Being sessile, plants have been forced to innovate because of this responsibility. To control the overall results of their interactions with microorganisms, they have developed methods. One of these ways is the utilization of chemical signaling, which is carried out by the plant's root system. The host cells' pattern recognition receptors, which sense danger and enable the release of chemicals that attract helpful microorganisms while simultaneously repelling pathogens, mediate immune signaling pathways.

A considerable percentage of the plant's carbon is lost as a result of the signaling system, which might, in rare circumstances, result in pocket-sized growth and a poor yield. Exudates are the names for the chemicals that the plant's roots release. These exudates are continually produced by the roots, and once they have accumulated, they are released as diverse substances onto the rhizosphere's surrounding soil. Enzymes, water, hydrogen ions, mucilage, and carbon-containing primary and secondary metabolites are examples of compounds. Both the microbial symbiont and the plant host are impacted by plant-microbe relationships. The symbiotic bacteria that are present in the environment, as well as the competition for soil nutrients, have a significant impact on plant phenotypic and ecology. Microorganisms that are connected with plants engage in complicated interactions that influence plant ecology and/or diversity[1], [2].

The genotype of the plant has a major influence on the population makeup of the phylosphere, endosphere, and rhizosphere of microbes, according to recent developments in genomic technology. Recent research on plant exudates leads us to believe that the production of root exudates is a regulatory biocontrol mechanism designed to choose a certain soil bacterial population in accordance with the characteristics of the plants. Regarding the operation of ecosystems, the functions played by each of the players in plant-microbe interactions have been identified. Study on the interactions between microbes and plants has become simpler because to modern technologies, opening up new options and study avenues.

However, little is known about the precise workings of the processes underlying plant-microbe relationships. Understanding plant-microbe interactions is crucial because they have a significant impact on plant physiology and development. The survival or demise of the plant may depend on the presence or absence of a certain microorganism. However, it is crucial to remember that other elements, such as the environment, local creatures, and soil composition, play a significant influence in these plant-microbe interactions in addition to the host and the symbiont. However, it is crucial to remember that other elements, besides the host and the symbiont, play a crucial part in these interactions. These elements include the environment, local organisms, and the makeup of the soil. This chapter will describe the positive and negative interactions between plants and microbes, the bacteria engaged, the plants impacted, and the outcomes of these interactions[3].

Positive Connections

Connections that are convenient for the plant are beneficial interactions with respect to microbes and plants. These kinds of relationships are described as having a mutualistic character, where the interaction is advantageous for both sides. In these relationships, the microbe's presence grants the plant benefits that would not otherwise be possible without the organism, and the plant in turn gives the microbial symbiont food in the form of carbohydrates. According to new findings, fatty acids were shown to directly pass the mycorrhizal interface to the microbial partner, contrary to earlier theories that presumed hexoses were employed to transport carbon to the fungal symbiont, according to Kafle et al.

Regarding the plant, microbe, and general environmental circumstances around the plant, there are differences in the variables that the microbe provides to the host plant. Some of the advantages the microbe offers the plant include the ability to withstand biotic and abiotic stresses, the production of certain substances, such as phytohormones, which enhance plant nutrition and promote optimal growth and high yield, as well as defense against pathogenic microorganisms.

The interactions that arise between helpful microorganisms and plants also hold great promise for the development of agricultural agents that can help increase crop nutrient efficiency and stress tolerance, such as microbial fertilizers and bio pesticides, biocontrol agents, and agents used in rhizoremediation. The manipulation of advantageous plant-microbe interactions helps us understand more about the ecological functions of microbial populations for sustainable agriculture. Various microorganisms, including fungus and bacteria from different genera, are a few instances of the helpful plant-microbe interactions. Some of them are described further in this study.

Mycorrhizal Arbuscular Fungi

The colonization of ancestor filamentous fungus of the mycorrhizae was possibly the oldest and most ancient interaction between plants and microbes. The relationship included the mycorrhizal component helping the plant host consume nutrients and liquids, and the plant host responding by giving the mycorrhizal symbiont carbon produced via photosynthetic processes. Endomycorrhiza and ectomycorrhiza are the two categories under which mycorrhiza are categorized. The color, size, and structure of endomycorrhiza's roots are similar to those of typical plants, with the exception of hyphae that enter the cortical cells of plant roots to create arbuscules or vesicles. The endomycorrhiza is often referred to as a vesicular arbuscular mycorrhizae since it has both an arbuscule and vesicles. While many plants are incapable of these metabolisms, ectomycorrhiza metabolizes plant sugars for the plant, namely mannitol and trehalose. Additionally, ectomycorrhiza generate protease enzymes that lead to the protein breakdown of leaf litter. Additionally, ectomycorrhiza uses additional radicle hyphae to collect soil nutrients, transferring them to the plant through branching arbuscules.

Up to 90% of living plants in the modern world have symbiotic relationships with mycorrhizal fungi, with the AMF group accounting for around 80% of these relationships. According to earlier research by Kafle et al., 65% of all known species develop plant-microbe associations with AMF. The 15% discrepancy between these findings may be explained to the varied years in which the investigations were carried out by the various researchers as well as ongoing research that reveals further evidence of AMF interactions with plants. There are hardly more than 350 species of arbuscular mycorrhizae fungi, which belong to the subphylum Glomeromycota of fungi. For more than 400 million years, AMF has coexisted alongside plants while retaining its original morphology. The symbiosis is thought to be the most significant symbiosis on earth, however this is still up for debate.

According to the evidence of this symbiosis, the development of land plants was significantly influenced by the interaction between plants and AMF. All legumes and a few other plants, including several essential agronomically, interact with AMF. Wheat, maize, and rice are some key crops in terms of agriculture. Both sides benefit from the symbiosis between AMF and host plants. AMF transfers nutrients necessary for plant development by colonizing the roots of the host plant. The host plant reciprocates by giving the fungal symbiont between 20% and 25% of its photosynthesis-derived carbohydrates. Arbuscular mycorrhizal symbiosis is established when AM hyphae begin to colonize a suitable root. This is followed by the development of an appressorium and cortical penetration, which is where arbuscules are formed. The exchange of continuous signals between the symbionts is considered to occur prior to the start of colonization in order to prepare for and establish the colonization.

DISCUSSION

Growing Microorganisms for Plants

Because certain bacteria are pathogenic, interactions between plants and microbes sometimes serve as a battlefield for competition over scarce resources. Solutions to plant growth and development generating high yields of crops and protection against pathogens are particularly important for agricultural sustainability in light of the battle against pathogenic microorganisms that cause plant damage as well as significant agricultural losses. Fortunately, a variety of microorganisms found in the rhizosphere have the ability to restrict the development and activity of several soil-borne pathogenic organisms. These bacteria are known as plant growth-promoting microorganisms because of their capacity. A plant might go into defensive mode by way of induced systemic resistance, which is in charge of lowering the activity of dangerous microorganisms, as an example of rhizobacteria that promote plant development.

The plant's behavior against different biotic and abiotic strains is shown in Figure 6.1, with the ISR activated to help combat the impacts of the pathogenic onslaught. Pseudomonas and Bacillus species are the two rhizobacteria with ISR induction abilities that have been the most thoroughly researched.

Recent research has shown that L-malic acid secretions from plant roots only attract the bacteria Bacillus subtilis FB17, rejecting other Bacillus species. Selective behavior is a representation of specific rhizobacterial target signals, which are only compatible with the aforementioned bacterium and enable it to colonize the host alone. The selective behavior also reveals the plants' autoregulatory systems, which mediate and regulate root colonization and furthermore its extent, possibly as a measure of defense as well as a way to rein in carbon costs lost to the microbial symbiont Rhizobacteria take up residence in the rhizosphere, where they have beneficial effects on plants. Plant growth-promoting bacteria invade plant roots and provide the plant various advantages, including the production of chemicals that stimulate plant development.

The responses of PGPRs are comparable to the reactions of flavonoid-participating legume-rhizobia signaling pathways. The interactions between plants and PGPRs are modulated by substances secreted by the roots of PGPRs. The methods for releasing the appropriate signals by roots to attract different bacterial species, however, remain a mystery. Rhizobacteria that encourage plant development have a significant impact on the upkeep of soil fertility, which in turn encourages growth and simultaneously raises and improves agricultural yields. The advantages of PGPRs make them appropriate for use as biofertilizers. The demand for chemical fertilizers that are harmful to the health of people, animals, and plants would be reduced by the use of PGPRs as biofertilizers. Different chemicals are produced by PGPR interactions with plants, all of which are necessary for plant development. These substances include siderophores, phytohormones, and ammonia, which is created when nitrogen is fixed. PGPRs are also engaged in processes including the solubilization of phosphate, iron availability, and the ISR mechanism. Due to the manufacture of substances like hydrogen cyanide, which serves as a biocontrol agent for weeds, PGPRs have the potential to be used as a biofertilizer as well as having biocontrol properties. In addition to producing lytic enzymes that lyse parts of the pathogenic cell walls and inhibit their proliferation, PGPRs also generate antibiotics.

Rhizobia

Some nutrients or minerals are particularly scarce in the soil. However, these few minerals are essential for plant growth and development. Interactions between plants and microbes are helpful in these situations. One of the nutrients required for plant development is nitrogen, but there is relatively little of it in the soil. Fortunately, there is a group of bacteria that can convert air nitrogen to composites that contain nitrogen and are used by plants to thrive. These microbes are known as diazotrophs, or nitrogen-fixing microorganisms. Although certain archaea can also fix nitrogen, bacteria are often the ones that do it. Some of these N-fixing bacteria are referred to be free-living because they are able to fix nitrogen on their own, but others can only do so in symbiotic relationships. Along with AMF, nodule bacteria called rhizobia are among the most significant beneficial microorganisms. In a process known as nitrogen-fixation, Rhizobia forms a symbiotic relationship with leguminous plants and converts atmospheric nitrogen into ammonia. Rhizobia attach to plant roots, where the N-fixation process takes place. Rhizobia are subsequently secreted to the host plant, which in turn receives dicarboxylates from the leguminous plant[4].

Endophytes

Microbes that live within plant tissue are called endophytes. Bacterial or fungi endophytes are both possible. From the production of growth-inducing metabolites and phytohormones to improved nitrogen nutrition in diazotrophic endophytes, 1-aminocyclopropane-1-carboxylate deaminase biosynthesis, phosphate solubilization, and inhibition of pathogenic microbial growth, associations between these endophytes can be very advantageous for the plant host. Endophytes have the ability to promote plant growth either directly or indirectly, with the former utilizing nitrogen fixation, the production of plant regulators such as auxins, gibberellins, and cytokines, the inhibition of ethylene production by ACC deaminase, as well as the alteration of sensory mechanisms of sugar in plants. Pathogenic activity is blocked by indirect mechanisms. Transformations of chemical processes and trehalose biosynthesis activities in plants that provide them a tolerance for abiotic challenges are two examples of positive endophyte interactions with plants.

Pathogenic Interactions

Plant-microbe interactions that cause damage to the plant are called pathogenic interactions. These relationships, which are considered parasitic interactions, exclusively benefit one partner while harming the other. Not only will the parasitic microbe compete with the host plant's beneficial microbial symbionts for resources, but it will also infect the plant and spread disease, which will eventually kill it either by severely depleting plant resources and inhibiting growth and yield, or by severely harming the plant's structure. Since the beginning of civilization, plant diseases have decimated crops, producing substantial agricultural losses as well as negative impacts on human health. Plant diseases brought on by infections continue to be the main culprits behind severe human suffering and financial losses. Both via the rhizosphere and directly through the plant tissue above the soil, pathogenic microorganisms may enter the plant.

Dou and Zhou claim that a wide variety of tiny organisms live on plants, some of which are capable of triggering infections that may lead to illness. Only a tiny percentage of pathogens can effectively infiltrate plant hosts and cause illness. However, plants have developed defensive mechanisms to fend off pathogenic invasions, such as the hypersensitive response, which is a rapid defense reaction created by plants when attacked by pathogens and serves to identify and fight invasion. When HR reacts, the original infection site undergoes localized apoptosis, which stops the illness from spreading further. Through selective apoptosis, sometimes referred to as programmed cell death, the HR response limits the proliferation of the pathogen. Additionally, PCD-related behaviors cause a nonspecific resistance known as systemic acquired resistance. SAR makes sure that disease resistance is preserved for a long time, defending the plant against many infections. Although plant-associated bacteria have mechanisms that help the plant defend itself via ISR, other microorganisms, like oomycetes, are difficult to combat or even genetically alter. In addition to oomycetes, other diseases that harm plants include fungus, bacteria, and viruses, all of which have detrimental effects on how they interact with plant life[5].

Oomycetes

Along with fungus, oomycetes are one of the main plant diseases. They are categorized as belonging to the Protoctista kingdom. Oomycetes are similar to fungi in that they produce mycelia with the development of spores that they employ for both asexual and sexual reproduction. They also create filamentous growth when in their vegetative stage. Oomycetes reproduce sexually by producing oospores as a consequence of male antheridia's hyphae coming into touch with female oogonia, whilst sporangia produce zoospores as a result of their cytoplasmic cleavage during asexual reproduction. The sporangia that give birth to zoospores enable oomycetes to be dispersed by wind and water, and zoospores that swim in water to eventually reach plant surfaces where they adhere via adhesion molecules[6].

Oomycetes, in contrast to certain fungi, provide a difficulty since they are difficult to manipulate genetically. Oomycetes have many methods for colonizing the plant host, much as fungi do. Oomycetes may colonize in a biotrophic, necrotrophic, or hemibiotrophic manner. The oomycete thrives and reproduces within the live plant tissue by taking the nutrients from the plant during biotrophic colonization, which entails tight interactions with living plants. Necrotrophic colonization, on the other hand, is the polar opposite of bio trophic colonization in that the oomycete first consumes the plant tissue before colonizing it.

The final method of oomycete colonization, known as hemibiotrophy, is a combination of the colonization lifestyles mentioned above. In this mode, the oomycete initially colonizes in a biotrophic manner, but as the interaction progresses, over time the host plant cells eventually die, leaving the oomycete to feed on the dead cells, changing its lifestyle from biotrophic to necrotrophic. Some of the oomycetes that have been linked to many plant diseases have been shown to harm a variety of plants. One such plant pathogen is the oomycete Phytophthora. The most researched oomycete genus is Phytophthora, which affects a wide range of plants, including potatoes, cocoa, soybeans, and even several types of forest trees found in California and Australia.

Fungi

One of the main plant infections is the fungus, and some study indicates that they may provide the most varied array of ecologically and economically significant dangers. The phyla Ascomycota and Basidiomycota are where you may find the majority of fungal diseases that damage plants. A significant portion of agricultural losses are caused by fungus-based plant diseases. They reduce the quality of fruits, vegetables, and plant matter in general. In their infection mechanisms, they use conserved proteins. Therefore, it seems sense that knowledge of these conserved proteins would be essential for managing fungal illnesses. Similar to oomycetes, fungi have three different modes of colonization: biotrophic, necrotrophic, and hemibiotrophic. These colonization modes distinguish between different fungi species based on how they live in relation to their plant hosts and how they obtain their food. The classification for lifestyle is the same as for oomycetes, which live a biotrophic lifestyle that involves close contact between the fungus and its plant host, establishing itself in the host's living cells, and concurrently consuming live plant tissue. The same is true for fungi that live a necrotrophic lifestyle, in which they first consume their host plant before feasting on their dead cells. This suggests that the hemibiotrophic relationship between fungi and plants will also be similar to that of oomycetes, with the fungus starting out in a biotrophical relationship with the plant until a point where the plant is killed by the fungus's gradual infection, at which point the fungus will change its lifestyle to a necrophytic one by consuming the dead cells of the plant host[7].

For reproduction, the pathogenic fungus produce both spores and filamentous growth. The spores are spread by wind, water, and insect-borne vectors, and once they touch a plant's surface, they cling to it tightly to prevent being washed away. Examples of plant pathogenic fungi include the biotrophic fungi Ustilago maydis, which also causes smut disease on maize and teosinte, and Cladosporium fulvum, which causes tomato leaf mold. These biotrophic fungi are special in that they resemble endo-phytes in that they lack haustoria, unlike other fungi and oomycetes. However, the pathogenic fungi have the ability to create specific infection structures like appressoria, which enter the host cell. Through their assistance in enabling the complete capabilities of the virulence protein, peroxisomes play a crucial part in these processes.

Bacteria

Bacteria are tiny, single-celled creatures that have just recently been shown to be harmful to plants, causing plant disease. Although not as badly as fungi and viruses, plant bacterial pathogens are to blame for major plant illnesses. Pathogenic bacteria harm plants less cheaply and with less expense than fungi and viruses. It should be noted, however, that bacteria are capable of causing severe economically damaging diseases that begin with very minor symptoms like spots, eruptions, and swelling that can be seen on the surface of the plant, such as on the leaf or the flesh of fruits, and progress to severe rotting of bulbs that is indicative by the exudation of putrid smells, and ultimately result in the death of the infected plant.

Any plant can develop plant bacterial pathogens, which can cause bacterial diseases. These pathogens can cause fasciation, which is a distortion of the leaves and shoots caused by hormones, as well as crown gall, which is an enlargement of the soil, stem, and roots. There are many possible paths that a pathogenic infection caused by bacteria might take, and there are theories that the whole situation only occurs passively as a result of unintentional instances. Pathogenic bacteria are thought to be able to enter plants by natural holes like stomata, hydathodes, or lentils. However, in rare instances, seed immersion into inoculum or wounds or abrasions to the plant's hosts roots, stem, or leaves caused by insect eating might cause the plant to acquire the bacterium. Following bacterial entry into the plant host, the bacterial pathogen attaches itself to the host plant. Pili, a kind of polymeric organelle that resembles hair, aids in this adherence. After colonization is established, disease signs such as wilts, spots, blights, crankers, and galls begin to manifest.

Viruses

Viruses, which are very tiny creatures, are known to infect all living things, including bacteria, fungi, animals, plants, and bacteria. Since viruses are obligate parasites, which means they exclusively rely on their hosts for existence, no virus has ever been found that can survive on its own. Even though little viruses have developed ways to live, they still carry the nucleic acids of the three proteins that make up their genetic material, which they inject into a host after they have identified it. This allows the virus to replicate and grow inside the host. Interactions between viruses and plants are severely harmful to the plant. They spread severe illnesses that result in catastrophic losses in agricultural production and quality, which generate economic losses on a global scale. Plants with virus-caused illnesses provide a challenging problem since they are extremely difficult to treat, and efforts to do so inevitably end in the plant's death[8].

One of the first human-made connections on earth was the interaction between plants and microbes. All life forms on our planet may have their origins in the mere presence of these interactions. These relationships are still changing after millions of years have passed, but nothing is understood about the complete methods they operate by. It is clear that more study needs to be done to understand the entire processes at play in these correlations. Undoubtedly, a thorough knowledge of these relationships and the mechanisms behind the results they produce would result in ground-breaking innovations or improvements for both the agricultural industry and the earth as a whole.

According to the majority of research investigations conducted so far, a wide range of pathogenic organisms seem to have a significant impact on the model plant genus Arabidopsis. It seems that practically all of the diseases mentioned above have the capacity to infiltrate this genus.

It is amazing that this genus hasn't developed better ways to protect itself from the many infections that appear to be able to easily get past its defenses given the numerous defensive mechanisms that plants have evolved since the start of civilization. However, this data may also be a result of the model plant's extensive study or perhaps its adaptability to host a variety of species, which makes it the perfect plant for research. More study of the relationships between plants and microbes might lead to a greater understanding of these relationships as well as potential to generate biological molecules that could help address the present climatic concerns brought on by the overuse of hazardous chemicals.

CONCLUSION

Plants and the ecosystem as a whole benefit from study on processes like the exploitation of some of these plant-microbe interactions to generate biofertilizers and biopesticides. These biological processes are made feasible by studying the interactions between plants and microbes and stop the usage of chemical and hazardous pesticides that are contaminating more soil and water. They seep into the ground and are leached into the soil, disrupting the normal microbiota, contaminating subsurface water, and thus reducing biodiversity. A potential endeavor made feasible by the ongoing research of these interactions between plants and microbes is the application of bioremediation to remove poisons from the environment. The underlying regulatory mechanisms that imply interactions between plants and microscopic organisms might be useful as biocontrol agents are supported by pharmacological and molecular investigations.

The use of eco-friendly bioinoculants, which have no negative effects on crop development, will significantly reduce the use of toxins and their presence in the environment, thanks to processes associated with beneficial plant-microbe interactions. On the other hand, pathogenic interactions provide insight into how the processes they go through may be utilized to generate ideas on how to manage or at the very least reduce or combat pathogenic organisms on plant life. The use of pathogenic pathogens as biopesticides that work against other diseases, especially insects, might prove to be highly successful. Plants have anti-pathogenic defensive mechanisms, which, with more study, may provide an intriguing approach for better comprehending pathogenic processes. Along with HR, SAR, and ISR, plants also have self-defense mechanisms made up of chemical and biological components, some of which are already present, including toxic exudates that protect against pathogenic spores.

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CHAPTER 7

FORMULATIONS FOR BIOFERTILIZERS

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ABSTRACT:

The need for fertilizers has risen due to the expanding human population and the need for sustainable agriculture. To minimize the harmful effects of chemical fertilizers, recent breakthroughs recommend using fertilizers based on microorganisms. Biofertilizers are preparations that comprise active or dormant microorganisms supported on an appropriate carrier material that is safe for the environment and simple to use. The selection of a specific microbe, the choice of an appropriate carrier material, and the formulation process are all essential components of a full formulation strategy. Additionally, various chemicals and ingredients for sticking are added. Numerous reports have been made on microorganisms such bacteria, algae, fungus, and actinomycetes. Four distinct types of formulations are created depending on the inoculum. Carrier substances including peat, wheat bran, talc, and vermiculite are often used in carrier-based compositions. Granular formulations contain peat prills to prevent the negative effects of powder formulations. In order to facilitate handling and increase formulation efficacy, liquid formulations are developed. Additionally, cell immobilization is the most recent formulation type that minimizes all of the limitations of earlier formulation types. The stages involved in formulation strategy are all presented and explained in this chapter, with an emphasis on how they might be used to improve quality control.

KEYWORDS:

Biofertilizers, Biofertilizer formulations, inoculants, inoculant preparation.

INTRODUCTION

It is impossible to disregard the contribution of conventional agriculture to the provision of food for people. However, the ongoing growth of the human population necessitates the use of sustainable production methods. The amount of land used to grow food has been replaced by the human population. In order to supply the expanding demand for food, it puts strain on agricultural resources. Therefore, there is a pressing need to implement certain cutting-edge technology that might meet the food needs of 7.6 billion people, which is predicted to rise to almost 10 billion by 2050. The issue of feeding this expanding population is enormous. Only pesticides, chemical fertilizers, or both could make it conceivable. Chemical fertilizers have seen extensive usage since the Third Agricultural Revolution. Chemical fertilizers are mixtures comprising different macronutrients and micronutrients that, when used on a plant or added to the soil, may improve the soil's fertility and promote crop development. For agriculture to be sustainable, essential nutrients must be present in sufficient quantities. NPK fertilizers, commonly known as nitrogen, phosphorus, and potassium fertilizers, have a high production demand and provide N 2CO, NH4NO3, P 2HPO4, superphosphates, and K in compound forms.

However, the more widespread use of chemical fertilizers generated major environmental concerns and left the soil deteriorated, severely contaminated, and incapable of producing food. These dangerous chemicals cannot be absorbed by plants, so they begin to build up in the soil and eventually end up in groundwater. These substances cause disease occurrence, soil acidification, eutrophication of water bodies, and weakening of plant roots. In addition, nitrates may lead to "acquired methemoglobinemia," often known as Blue Baby Syndrome, a serious illness. The overuse of chemical fertilizer led to severe abiotic stress, which had an impact on sudden temperature changes. Given the global increase in food consumption, using chemical fertilizers is unavoidable. However, organic farming has emerged as a viable option in terms of producing wholesome food that is also environmentally friendly and long-lasting due to the negative impacts of using chemical fertilizers over an extended period of time. In this sense, the usage of Biofertilizers is an example of organic farming.

When given to certain crops, roots, seeds, or soil, Biofertilizers natural or man-made compounds containing live or dormant strains of effective microbes supplement the plant by colonizing the rhizosphere or directly reaching the roots. By providing a continuous stream of micro and macronutrients, Biofertilizers benefit plants. These are also known as "bio inoculants" or "microbial inoculants" at times. "Nitagin," the first commercially accessible Biofertilizer, was created by Nobbe and Hiltner in the United States in 1896. This organic fertilizer did not get much attention at the time. Nevertheless, the National Project on Development and the Use of Biofertilizers was set up by the Ministry of Agriculture and Farmers as part of the Ninth Plan. Due to its distinct characteristics toward less environmental consequences, greater plant growth, and therefore increased output, Biofertilizers have since become a need for plant development and production[1].

Biofertilizers: A Sustainable Method

Chemical fertilizers unquestionably contributed to significant environmental contamination in order to meet the population's ongoing need for food. Additionally, there has been significant harm done to natural microbial habitats and helpful insects. However, the indiscriminate use of such chemicals has reduced the crops' ability to fend against disease-causing bacteria. In light of all the negative impacts, Biofertilizers have been shown to be a secure alternative to chemical fertilizers that cause the least amount of ecological disruption. Biofertilizers have been shown to improve the levels of vital amino acids, nitrogen fixation, vitamins, and proteins, which increases yield by 10% to 14%. The phrase "Biofertilizer," also known as "microbial inoculant," is sometimes misapplied to chemical fertilizers and animal manure products that are organically augmented and used in intercropping. However, microbial inoculant is a product that may replenish the targeted plant when applied to either roots, soil, or plant surfaces. It contains live or latent microorganisms supported on a carrier material.

Biofertilizers do not provide nutrients directly to the plant, in contrast to chemical fertilizers. They either colonize the rhizosphere or reach the roots directly, promote plant development, make nutrients accessible, shield plants from ecological stresses, and improve their resistance to heavy metals, fluctuating temperatures, salt, and drought. Additionally, they increase the concentration of crucial nutrients in plant roots and solubilize minerals to make nutrients more readily accessible. As a result, the microbial activities in the soil are hastened, increasing the amount to which the nutrients are available and increasing the soil's fertility. Only three or four nutrients are supplied back to the environment for every 17 that plants need to flourish. The soil becomes inadequate for development when nutrients are continuously removed through it. The elements that replenish the nutrients and maintain the soil's nutrient buffer are known as Biofertilizers. Biofertilizers have no negative impact on the environment, plant health, or soil composition. Formulations for Biofertilizers

A preparation known as Biofertilizer may include active or inert microorganisms, and its composition allows for simple handling, an extended period of storage, as well as Biofertilizers effectiveness. A Biofertilizers formulation serves as a vehicle to transport microorganisms from the production facility to the field. As a result, bio formulation displays a carrier state for active or latent bio inoculants that are given to the intended spot, either directly to the plant or to the soil. The kind of microbial strain and the formulation of the inoculum are the two key determinants of the success of inoculant technology. Practically, the formulation technique of a Biofertilizer determines its likelihood of success. According to the kind of soil, the application's interest, the resources at hand, and the type of plant, a formulation may be changed. A strain must be chosen, a carrier for carrier-based inoculants must be chosen, and finally a formulation strategy must be chosen.

Strain Selection

One crucial step in the strain selection process is the creation of appropriate inoculants. Therefore, the chosen organism as strain must be extremely efficient and competitive toward native populations already existent in the soil. Both must be compatible in order to create an effective inoculum since it is better to utilize a mix of strains rather than a single one. The utilization of the following strain types was reported in recent investigations.

Microbial Strains

Bio inoculants are the live or dormant microorganisms that carry Biofertilizers. Commercially, several inoculants are employed for the Biofertilizers. Depending on the kind, these microorganisms fix nitrogen or solubilize a variety of soil nutrients. They include bacteria, fungus, algae, and actinomycetes. While based on purpose, Biofertilizers might be symbiotic mycorrhizae, N2 fixers, P solubilizes, phosphorus and K mobilizers, etc. Plant growth-promoting microorganisms are the principal microbial strains that are employed in the formulations. The kind of PGPM utilized for the formulation depends on the type of crop, the surrounding environment, and the area that will be employed[2].

Bacterial Strains

An effective nutrient buffer is soil. It comes with a variety of bacterial populations that may be harmful, advantageous, or neutral. These bacterial species compete with the plant for niches or needed nutrients under a variety of circumstances. There are several ways that helpful bacteria may function. They either interact symbiotically with roots or grow freely in the soil. Whatever their shape, bacteria are able to store nutrients and establish colonies in the rhizosphere. Active plant roots exude substances that draw bacteria in and lead to a connection that improves the availability of nutrients in the particular root location. Additionally, they release Indole-3-acetic acid, a growth-promoting substance that aids in the stimulation of all growth. The ability to withstand abiotic stressors and plant diseases is improved by these compounds. These helpful bacteria may be categorized into two distinct kinds based on their modes of action, which are plant growth and health promoters. When infections are absent, plant growth promoters feed the plant by giving it nutrients and growth-promoting chemicals. The group contains mobilizers, phosphorus solubilizes, growth stimulants, and nitrogen fixers.

While plant health enhancers support growth during abiotic stress and when a pathogen is present. Either they lessen the harmful effects of infections or they directly stop the pathogen. Bacterial strains often exhibit potential pathways for growth promotion that aid plants in absorbing and using nutrients. Rhizobacteria, which stimulate plant development, and many endophytic bacteria that may coexist in symbiosis or not, follow nitrogen fixation. In particular, Azospirillum is one of several plants that participate in the excretion of phytohormones. The excretion of IAA occurs during both physiological and morphological changes in infected plants. The slower growth rate has led to ethylene exposures. The PGPR may increase growth rate by reducing ethylene levels. 1-Aminocyclopropane-1-carboxylate, which is the precursor of ethylene, is hydrolyzed by bacteria. Products of hydrolysis are often utilized by the bacteria as a source of nutrients. Lump chrome synthesis, phytase degrading chemicals, volatile compound generation, and mineral reduction through phenazines are a few examples of novel methods. Using any of these potential processes, creatures may assist the plants' nutritional needs. A few potential methods used by drugs that promote growth and an overview of plant inoculation by several bacterial strains.

PGPR

The rhizosphere is a repository made up of a certain amount of soil with an overabundance of bacteria around plant roots that are impacted by root exudates. It is an ecological niche where plant roots are a center of physical, chemical, and biological activity. The bacterial population in the rhizosphere is often 100–1,000 times larger than that in the surrounding soil. Bacteria have a wide range of metabolic capabilities that enable them to effectively stimulate and use root exudates. Furthermore, microbial organisms, which include several bacterial species, covered 15% of the plant root surface. Plant roots release around 5% to 30% of their photosynthetic products into the rhizosphere, where they are eaten by microbial communities.The rhizosphere is a source of mineral nutrients that are transferred and subsequently absorbed by plants as a result of subsequent metabolic processes. Algae, fungus, protozoa, actinomycetes, and bacteria are among the organisms that colonize the rhizosphere. However, owing to its distinct properties that promote development, bacteria have established themselves as the most prevalent microorganism in the rhizosphere. Two types of helpful rhizosphere bacteria have been identified[3].

DISCUSSION

The PGPR is a collection of heterogeneous bacteria that occurs in the rhizosphere, at the surfaces of plant roots, or in special relationships with roots, and which, in the end, enhances and promotes either the qualitative or quantitative aspects of plant growth characteristics. The term "PGPR" was initially used by Schroth and Kloepper to refer to advantageous bacteria present in the rhizosphere. They can also manage microorganisms that are phytopathogenic. The active ingredient in Biofertilizer formulations is PGPR. Two alternative approaches exist for PGPR to engage with plants. One is the so-called symbiotic connection, in which bacteria inhabit plant bodies and survive there by directly exchanging metabolites. The other is free-living, outside the plant body, rhizobacteria. Symbiotic bacteria in host plants typically reside in intercellular spaces, although certain bacteria interact mutualistic ally and infiltrate the host plant. Additionally, a small number of bacteria have the capacity to combine their physiology with that of a host, developing specialized structures. A group of mutualistic bacteria known as rhizobia have a symbiotic connection with the legume family in order to fix atmospheric nitrogen in a specific kind of root structure known as a nodule and make it accessible to the plant for use.

There are two possible ways that PGPR may act: an indirect mechanism and a direct mechanism. Microbes function directly inside the plant in the direct mechanism, which also involves bio fertilization, rhizoremediation, growth stimulation, and stress management in plants. While the indirect management method minimizes the effects of illnesses like antibiosis, the development of systemic resistance, and competition for nutrients and niches outside the plant. Biological N2 fixation, P Solubilization, and phytohormone production are examples of direct mechanisms. Root/legume symbiotic bacteria, especially Rhizobium, have the selectivity for plant roots that eventually form root nodules in biological nitrogen fixation. Free-living bacteria, including Azospirillum and Azotobacter, fix nitrogen but lack specificity. Bacteria convert organic phos-phorus into inorganic forms that plants may use. The main process for the release of organic acids from sugar metabolism functions as a chelator of Ca2+ to help produce inorganic phosphate. For instance, Gibberellins released by Pseudomonas and Bacilli impact developmental processes like as blooming, seed germination, and fruit set. Pseudomonas and Bacilli also produce IAA, a key auxin required for plant growth.

Nitrogen fixation for plants, plant growth regulators, abiotic stress tolerance, production of ACC-deaminase, chitinase, and glucanase, which are protection enzymes against various plant diseases, volatile organic compounds, and siderophores are all part of the role of PGPR for enhanced plant growth. Their manner of action, however, often varies due to different host plants. Soil stresses, which come in two varieties biotic and abiotic are significant barriers to sustainable agriculture. Abiotic stressors are brought on by the presence of heavy metals in the soil, nutrient shortage, temperature, drought, salt, and other factors. Biotic stresses are mostly caused by plant diseases such bacteria, nematodes, and viruses. Products made from Biofertilizers including PGPR have been reported and utilized all over the globe, improving crop output and soil fertility. The promise of PGPR has therefore led to sustainable agriculture. Composts and PGPR together may promote plant development and biocontrol. Falciparum spp. Bacillus spp., too. Are PGPR, which have been acknowledged as potent biocontrol agents? Rhizosphere formation is made possible by PGPR when Biofertilizer levels are high enough for plant development. Nutrient availability is increased by PGPR, which also reduces pathogenic activity. The increased availability of nutrients may increase soil fertility, improve biocontrol outcomes, and increase the survival rate of soil microorganisms. The usage of several bacterial strains in various Biofertilizer formulations is explored.

Algal Species

Microalgae have received a lot of interest among previously reported formulations based on microorganisms, such as bacteria, prokaryotic cyanobacteria, and fungus. They are employed all over the globe due to their outstanding potential for enhancing agricultural productivity and soil fertility. Algal formulations have a well-known function as Biofertilizers in agricultural systems. However, by controlling the water flow into the soil and therefore enhancing the soil's fertility, algae have shown their ability to reduce soil erosion. They have also contributed significantly to the biocontrol of viruses and pests as well as wastelands. In wastewater treatment and macrobiotic crusts, algae play an important role. Every year, microalgae, particularly cyanobacteria, are employed as a Biofertilizer. There are also several sporadic reports about employing green algae. Euglenophyta, Rhodophyta, Pyrrophyta, Chrysophyta, Phaeophyta, and Chlorophyta are the different subgroups of microalgae. Both algae and cyanobacteria are photosynthetic organisms that are employed as Biofertilizer strains and soil conditioners.

Prokaryotes that can make oxygen only include cyanobacteria. Since the 1950s, when the productivity of algal biomass and yields was investigated, extensive research on algal industrial uses has been carried out. On places that are not profitable for agriculture and need little freshwater input, algae may grow quite well. The major advantages of algae are that they may be grown in large quantities of agricultural runoff and wastewater, collecting extra nutrients and regenerating water for use in subsequent agricultural operations. Additionally, they may be utilized to reduce greenhouse gas emissions by sequestering CO2 and NOx from industrial sources. The simplest surviving autotrophic plants, cyanobacteria are found throughout seas and are capable of turning inorganic substances into nourishment. Cyanobacteria are a valuable source of Biofertilizer for enhancing the composition and physio-chemical characteristics of soil thanks to their special abilities to fix atmospheric N2, adapt to unfavorable severe circumstances, and store large amounts of water. Cyanobacteria release hormones that stimulate plant development in the form of secondary metabolites, control how nutrients are transported from the soil to the plant, and enhance the chemical composition and soil agglomeration. Cyanobacteria may spread widely across an ecosystem due to their various morphology and physiological characteristics, and they can also withstand environmental challenges [4].

Fungus Varieties

According to a fossil research record, mycorrhizae have been associated with plants since at least 400 million years ago. This has led to the theoretical presumption that the emergence of plants may have been influenced by these early symbiotic connections. All plants analyzed have been shown to be in a symbiotic relationship with fungus since the earliest recorded plant-fungal association. A symbiotic connection between fungi may display mutualism, commensalism, or parasitism, a relationship in which it can have a positive, neutral, or adverse impact. Mycorrhizae are common non-pathogenic organisms that form symbiotic relationships with plants, either naturally or in cultivated environments where there is a two-way exchange of nutrients. Fungi get sugar from plants, which aids them in acquiring soil nutrients. Mycorrhizae are divided into seven categories based on their structural and functional properties. Frank formed mycorrhizae into the two significant subgroups of end mycorrhizae and ectomycorrhizal.

In an association, ectomycorrhizal fungi create a mantle network of hyphae in the plant roots. Arbuscular mycorrhizae, monostrophic mycorrhizae, ericoid mycorrhizae, ectomycorrhizal, arbutin mycorrhizae, and orchid mycorrhizae are the several types of endomycorrhizal fungus. Each class varies in the intracellular hyphal establishment, although they all share the fungal hyphae's habitation of root cells. AMF are obligate symbionts and are members of the phylum Glomeromycota.

As it delivers P via the rhizosphere, AMF is particularly important for plants that lack phosphorus. AMF creates more diverse arbuscules than ECMF since they often symbiotically interact with herbaceous plants. Ascomycetes and Basidiomycetes are often seen in ECMF. Deep in the soil, the mantle network is what is directly responsible for mobilizing, absorbing, and moving water and soil nutrients to the roots. There is evidence that these two mycorrhizal groups increase resistance to pathogens, heavy metals, and drought. Thus, they play a crucial part in forestry and agriculture that are sustainable.

Actinomycetes

Besides fungus, PGPR, and other actinomycetes, the microbial community also includes algae. In the soil, there are around 100 genera of actinomycetes. These unicellular bacteria form a significant portion of the microbial population, particularly in alkaline environments. There aren't many research on actinomycetes as Biofertilizers, however. They may be utilized to enhance soil quality since they contain cellulolytic and phosphate solubilizing characteristics. Although they are plentiful just near to the bacteria, they move somewhat slowly. They degrade different materials more slowly than bacteria and fungus, including lipids, polysaccharides, cellulose, proteins, and organic acids. Dicko chose three actinomycete strains, and the yield and growth of the corn were examined to produce the formulations. Results were significantly different from controls.

Powder and Carrier-Based Formulations

Carrier Material Selection

The use of inoculants is made more difficult by the salinity, modest resilience to temperature changes, and inadequate nutrient delivery that dry and semiarid soils are especially prone to. The microbial inoculants crucially struggle with rhizosphere colonization and survival issues, which has an impact on plant health and growth production. Poor microbial occurrence, impossibility of PGPM development, and disease mitigation occur in arid soils. The distribution of bio inoculants was rendered effective in demanding circumstances under agricultural systems, nonetheless, thanks to enhanced formulation techniques and the utilization of carrier molecules. The carrier substance functions as a delivery mechanism to move active or dormant microorganisms from a commercial manufacturing facility to the rhizosphere. It must be produced via an effective carrier to ensure high-quality inoculant. A suitable carrier material should be able to provide an adequate quantity of microbial cells at the appropriate moment in a particularly excellent state[5].

Peat

The most popular kind of microbial inoculant carrier material utilized globally is peat. It is often used in the production of legume inoculants because of its capacity to defend against bacteria. In multiple research, it was agreed that the use of peat as a carrier for bacterial species is still preferred and uncontested. Peat is created when vegetation partially decays over an extended period of time. The development of microorganisms on the surface of particles and in their crevices is caused by the protective and nutritive environment it provides. Peat must have a high organic content, be non-toxic, very absorbent, have a strong water holding capacity, be simple to sterilize, and be cost-effective to utilize in order to be an acceptable carrier material. It also has a lot of surfaces, which helps inoculants develop rapidly. Governmental organizations often know how to regulate its quality. The bacterial population is also metabolically active, and in certain formulations, it keeps expanding throughout storage. Peat is widely utilized as a carrier material owing to its abundant availability, however processing it requires a multi-step procedure that is expensive.

Formulation of Inoculants

The traditional methods for making inoculant require inoculating neutral, non-sterile peat as a carrier with 107 CFU of a bacterial strain for a high degree of strain in the inoculant. By inoculating 104 CFU/g of the carrier, an inoculant with a large number of viable cells may be created. Maximum bacterial growth occurs in the inoculum up to a density of 108–109 CFU/g in fierce competition with contaminants. To remove the rough and coarse particles before slowly drying to 5%, the harvested crop is drained and sieved during inoculum preparation. The drying process is especially important since poor work practices might contribute to the generation of toxins. As air drying prevents the generation of pollutants, it should be preferred over oven drying. However, the temperature should never go over 100°C while drying items in an oven. The amount of drying is dependent on the kind and size of the peat particles, but the moisture content shouldn't be too high so that the finished product has the proper moisture level. Peat is sufficiently powdered after drying to pass through a filter with a mesh size of 250. The carrier is normally acidic, thus the pH level is changed to between 6.5 and 7.0 by liming. The carried is sterilized, and enough liquid inoculum is introduced. In bacterial compositions, moisture levels between 40% and 55% are acceptable. Finally, the infected carrier is incubated for a certain amount of time to allow for bacterial proliferation. The transport material for ectomycorrhizal inoculants and AMF may be peat.

Formulations for Biofertilizers

There are a few major disadvantages of using peat as a transport material. The efficiency of inoculants created by manufacturers and across various batches created by the same manufacturer depends on the source of the peat and is very varied. Peat inoculants often have high levels of pollution, which shortens their typical shelf life. Additionally, they have a limited tolerance for temperature changes and, during heat sterilization, emit hazardous components. Peat sometimes inhibits plant development and develops interfaces during the seed monitoring process.

Only a small number of nations have access to them. Typically, peat powder from the seed surface is blown off prior to seed air delivery of inoculant. Because of all the drawbacks of peat, experts started looking for alternatives. Peat is still used in Biofertilizer formulations, however. A number of changes have been made to improve the formulation's efficiency with several bacteria. Chitin, pyrophyllite, an Aspergillus Niger mycelium, and compost generated from Agaricus bisporus were used to modify peat. When formulations were employed for seed treatment, they enhanced strain development and encouraged seed germination, which in turn increased plant growth and yield.

Wheat Bran

Due to its high organic content and ability to preserve water, wheat bran has been utilized as a particularly effective carrier for the mass development of ectomycorhizae and phosphate-solubilizing fungus. As opposed to the Bacillus spp. and Pseudomonas species. However, it has been shown that some phosphate-solubilizing fungus cannot grow in the substrate because it lacks the cellulose enzymes needed to break down woody materials.

Talc

A silicate with mineral-hydrated magnesium is called talc. This is employed as a storage medium in the form of talcum powder, the softest substance ever created. Talc was often employed as a vehicle for the biocontrol agent Trichoderma viride. It was reported that the PGPR mixture-containing formulation was employed to control crop blight and increase grain production. The PGPR was created alone or in combination with talc- or wax-based formulations. Fusarium oxysporum gladioli, which evolved in gladiolus for corm and dust applications, were suppressed by talc-dependent inoculants of PGPR Burkholderia cepacia and Bacillus atrophaeus. The least amount of vascular wilt and the absence of corm rot in the greenhouse allowed for a 150% increase in corm production.

Biochar

Biochar is a kind of charcoal that is often created by the pyrolysis process, which involves the decomposition of organic materials at high temperatures with a limited amount of oxygen. Due to its uses as a soil amendment, it is distinguishable from charcoal. Additionally, it sees value in enhancing soil fertility and other ecosystem services that lessen the effects of climate change, such as carbon sequestration. However, there have also been claims that biochar is to blame for altering the soil's biological population. It is an excellent chance to utilize biochar as a carrier material for PGPR to transfer them into agricultural fields if we need to prepare biochar on a big scale for carbon sequestration. As a result, biochar may be used as a carrier material in place of scarce, costly, nonrenewable, and climate-changing carriers. Additionally, they have a large interior surface area with 2 to 20 micrometers of pore space, which offers a safe environment for microbial development. It is a pre-sterilized medium that may take in nutrients and growth ingredients thanks to the manufacture procedure.

Making Biochar

Glaser has shown evidence of increased plant output using biochar and bacterial inoculants. In a recent work, biochar from two different sources was used as a carrier-based formulation of Azospirillum lipoferum as an inoculant, and lignite was compared. Within 180 days of inoculation, the average population value of the carrier from the coconut source for both carriers was 10.7 CFU g1. For biochar made from coconut, the sprout vigor index for green gram was likewise high. Compared to lignite and charcoal made from acacia wood, Azospirillum lipoferum had a higher survival rate after 6 months of storage in the right population.

In another study, pinewood-derived biochar carriers that were pyrolyzed at 300°C and genetically modified to control inoculum as green fluorescent protein markers were developed were shown to be suitable. The addition of soil bacteria using biochar as a carrier medium significantly increased cell survival, according to a selective plate count experiment. The general bacterial population was not significantly impacted by the biochar carrier, however. The colonization of bacteria on roots after both of these treatments was quite comparable, with a root mass community density of 105 CFU g1. According to studies, inoculum has just a weak impact on the growth of plant production, however biochar has a remarkable impact. Compared to peat, biochar does not disintegrate as quickly into the soil, promotes bacterial survival, and benefits inoculated plants in the area.

Vermiculite

In the creation of bacterial inoculants, vermiculite is utilized as an alternative to peat since it is an efficient inoculant. This hydrated aluminum sili-cate alloy, which also contains magnesium, exfoliates at temperatures between 700 and 1,000 °C. Vermiculite may be produced for various bacterial inoculums without fermentation, which is more expensive, and specialized incubation equipment, making it ideal for many formulations. Vermiculite has various benefits as a carrier, including:

The degree of pollution is reduced by the exfoliation procedure.

1. It is inorganic because it was sterilized using standard procedures rather than high-temperature sterilization, which may produce hazardous compounds or alter the structure of an object.
2. It is quite affordable and widely accessible.
3. It has a multilamellar structure that allows for optimal aeration and serves as a breeding ground for microorganisms.

Vermiculite resists being crushed.

1. It serves as a chemical that promotes plant development.
2. Its 45–80 mm particle size gives it a superior ability to retain water and allows the formulation to adhere to the seed surface adequately.
3. One day following the manufacture of the inoculant, the quantity of microorganisms on the seed surface remains constant at room temperature.

Carrier Sterilization

By injecting certain bacteria, carriers may produce inoculants in both sterile and non-sterile conditions. It goes without saying that a sterile container is preferable than a non-sterile one. However, the sterile product has additional drawbacks, such as costly labor, more effort, and an aseptic packaging procedure. There are two types of formulations used: one for treating seeds and the other for direct soil application. Depending on the delivery mode, the formulae might be granules for direct soil application or powder treatment of seeds. Although strong formulations are often used, they have certain drawbacks in terms of expensive, labor- and energy-intensive processes. They also have a short shelf life, a tendency to cluster in different phases, high emission rates, poor uniformity, and variable field performance. Inoculant development nowadays entails innovative methods designed to improve inoculant efficacy, lengthen shelf life, and create a new generation of formulations. The most effective powder substitutes

Biofertilizers

The formulations that depend on liquids and alginates are called formulations. Customers may need modifications to solid carriers since they are currently engaged in other formulations.

Granular Formulations

A novel formulation, especially granular formulation, is generating a lot of attention as a way to reduce the unfavorable effects of powder-based inoculants. Granules are made using peat prills, silica grains, small marble pieces, or calcite material as beginning ingredients. The appropriate microbe is subsequently added to the granules. Although their granular sizes vary, the mother culture has found a strong link between the final product's quality and population density. Granules are far more effective than peat since they need less maintenance and are easier to work with. It's a complicated link between inoculants that rely on peat and granular. According to several research, rhizobia's granular formulation is not similar to peat formulations in terms of N2 fixation or nodule development. Several studies have shown that granular formulations are superior to liquid and peat formulations in terms of nitrogen aggregation, biomass, nodule size, nodule weight, and N2 binding. Granular formulations are employed specifically in soil stress situations as cold, damp, high acid stress, and moisture demand situations. On the other hand, since they are denser, it is challenging to get them to the fields, thus there are some disadvantages to this as well. The cost of storage and the degree of output, however, are much greater[6].

Formulations for Liquids

Mineral oil, oil-in-water, organic oils, polymer-based suspensions, and aqueous solutions are the principal ingredients used to create liquid inoculants. These are improved vaccines where "no formulation" vaccines have been developed. These are microbial cultures that have been enhanced with compounds that may increase a formulation's stickiness, stability, and dispersion capabilities. Because they are simpler to handle, mix, and administer to the soil and seedlings, liquid inoculants have proved helpful. Peat has historically been the most widely utilized carrier; however, due to its limited supply and increasing depletion, scientists are looking for the best liquid inoculant alternative for practically all kinds of Biofertilizers. Due to how easily liquid inoculants can be applied to seeds and transported via seed augers, modern seeding equipment quickly embraced them.

The following characteristics help to recognize the liquid inoculants:

Handling is a simple process; they enable the inclusion of chemicals and cell protectants that stimulate cell, spore, or cyst growth in the inoculants, so increasing the amount of nutrients given and thereby improving performance;

1. Show improved resistance to environmental stress;
2. Compared to formulations based on powder, are more effective.

3. They also act in a negative way on some level:
4. Liquid fertilizers may have a short shelf life;
5. Circumstances for low-temperature storage;

High manufacturing costs restrict usage mostly within rich nations while reducing use in developing nations; those bacteria that have a low chance of surviving, such Azospirillum sp. Do not look for assistance in creating a safe atmosphere; they are completely worthless.

Making Inoculants

The majority of liquid inoculum is created using a simple fermentation technique in which the fermentor is aseptically packaged and preserved without losing viability. Since the carrier material, which is often solid, does not need to be processed or sterilized, it is very inexpensive. Since liquid formulation involves a full sterilizing procedure, there was no contamination. It's a common misconception that a liquid inoculum is a fermentor broth culture or a liquid suspension of an inoculum made of solid material. Instead, it is a medium that supports microbial development and diverse cell protectants and contains nitrogen, carbon, and certain vitamin sources. The additives have properties that improve adhesion, inhibit osmosis, stabilize the product, boost rhizobial survival, and neutralize poisons found in seed coats. They further shield the inoculum from harmful environmental conditions. When an inoculum is ready, it is dissolved in a liquid, such as water, mineral, or any organic oil, and used to spray or dip the seeds for a period of time to inoculate them. After

Sewing occurs after drying. Without involving the seed inspection system, this strategy prevents the loss of inoculum and guarantees seed coverage. In soil when the temperature is extremely near to 40°C, legumes are seeded. These additives defend against high temperature and desiccation conditions, which seriously impair rhizobial life and their capacity to fix nitrogen. The quantity of bacteria in liquid cultures that contain cell protectants is kept high, and the production of resting cells such as cysts and spores is encouraged. These cells are resistant to adverse circumstances, which increases the survival of microorganisms[7].

Regular Ingredients

The capacity to preserve microbial cells during storage as well as on the seed surface when high temperature conditions and desiccation are present determines the choice of additives. High molecular weight polymers with strong water solubility, complex chemical makeup, and nontoxic properties are often ideal additives. Sucrose, glycerol, sodium alginate, carboxymethyl cellulose, polyvinyl alcohol, trehalose, polyethylene glycol, Arabic gum, polyvinylpyrrolidone, Fe-EDTA, and tapioca floor are examples of additives that are often utilized. When sucrose is introduced to a liquid inoculum, it helps bacteria and rhizobia that break down phosphate to survive. To prevent the cell from being dehydrated, the glycerol, which has a substantial quantity of liquid, slows down the pace of desiccation. In a research, Pseudomonas fluorescens was utilized as a strain, and it was shown that adding glycerol to the liquid inoculum production process kept the strain viable for 6 months while it was being stored. Additionally, Bradyrhizobium japonicum uses polyvinylpyrrolidone as a binding component in several formulations as a dehydration preventative and to reduce rhizobial-harmful seed exudates.

The ingredient carboxymethyl cellulose is widely used and is easily accessible. In contrast to other additives, it demonstrates consistent batch quality since it is a semi-synthetic polymer. It is also used in "1/5; w/v," an extremely low concentration that makes usage of it more cost-effective. Arabic gum, a complex combination of polysaccharides and glycoproteins, is another addition that is often utilized. It is also known as acacia gum since it is made from acacia. Numerous studies have shown its usage as an adhesion agent in numerous biofertilizer formulations, particularly rhizobia. When used in liquid formulations, it helps bacteria survive and guards against dehydration. The kind of additives used and their concentrations have a significant impact on the inoculum. It is very important to take additives and their kind into account while making the inoculum.

Cell Immobilization

For decades, scientists have been attempting to create unique formulations that have the most beneficial benefits while having the fewest negative ones. A recent advancement is the creation of a novel formulation termed cell immobilization. Cells may get immobilized in a variety of ways by being attached to the matrix or being entrapped inside it. Adsorption on surfaces, cell cross-linking, flocculation, covalent bonding with the carrier material, and encapsulation of the cells in polymer gel are a few examples of these. The most promising formulation method for creating effective carriers for microorganisms is encapsulation, which has a number of benefits over alternative carrier materials. The live cells are protected by encapsulation from predators as well as environmental challenges such temperature changes, organic solvents, toxicity, and other mechanical forces. When such formulations are applied to the soil, soil bacteria progressively break down the capsule, releasing huge numbers of the targeted cells into the soil, often at the time of seed germination or seedling emergence. When creating single or mixed strain formulations, such as rhizobia-AMF-based inoculums, the technology's ability to encapsulate bacteria, fungi, and tiny hyphal segments is highly helpful. Polymers, which may come from a variety of sources, are the most typical kind of materials utilized for encapsulation.

Formulas with Entrapped Polymers

Inoculant technology has advanced to the point that polymer-entrapped formulations are now possible. Following mass multiplication, the cells are combined with a specific polymer and given a chemical solidification treatment. It produced homogeneous beads with inside live cells as a consequence. The beads are fizzed in the matrix of polymer that promotes more growth, and then they are dried. As soon as the beads are placed in the soil, microorganisms there often break them down. Commonly utilized polymer materials might be synthetic or natural, as well as homopolymers, heteropolymers, and copolymers. According to a research, there are around 1,350 different material combinations that may be utilized as an entrapment polymer material. These combinations are chosen based on their chemical composition, molecular weights, and degree of interaction with other ingredients. Alginate beads and polyacrylamide are two of the most widely utilized polymer materials, although alginate is favored because of polyacrylamide's greater need for handling precautions[8].

Alginate

Alginate is a naturally occurring polymer that is now being used in formulations with polymer entrapment. It is derived in sustainable amounts from various bacteria and marine macroalgae. Alginate formulations sustain a high population rate and improve microbial inoculant survival at temperatures as high as 40°C. Several alginate-based inoculants are used for different organisms, and research into their use for agricultural purposes has been done. The results showed that polymer entrapped formulations were superior to all other formulations, such as polymeric formulations of AMF, ectomycorrhizae, and many P solubilizing bacteria. PGPMs may persist for a very long period in alginate polymeric material. Because the beads use less water than conventional polymer materials, the targeted bacteria are more likely to stay dormant and be released into the soil when moisture is present, which often coincides with seed germination. The field inoculation of formulations based on alginate reveals a high percentage of microbe survival and a comparable population to formulations based on other carriers. In comparison to direct inoculation, a research found that targeted beneficial cells delivered using polymeric material produced very effective outcomes for root colonization for the wheat crop.

Benefits and Drawbacks

They are much superior to traditional formulations in a number of areas, including effective carrying and strong handling and environmental stress tolerance. Despite being a relative success as shown by several laboratory tests, there is currently no commercial product accessible because of technical handling and very expensive manufacturing costs. The cost of labor that manufacturers and planters may embrace still has to be kept to a minimum.

Alginate is a pricey substance, as shown by the chemical industry's economic viability. However, the widespread manufacture of formulations based on alginate in Eastern nations has created a favorable chance for their usage as an inoculant in agricultural outputs. However, there have been several efforts to modify alginate by adding some other inexpensive substance that may serve as a carrier material. Alginate has been used in conjunction with several materials, including bentonite clays, rock phosphate, gypsum, talc, cement, granite powder, rock phosphate, and lignite, which might provide relatively cheap cost. Bacterial survival was markedly improved by the use of clay and skim milk in comparison to alginate alone. There have been reports of Rhizobium becoming trapped in alginate and perlite. Pero-dextrin, a byproduct of the starch industry, was also used. Pero-dextrin, Arabic gum, gelatin, and starch granules were mixed together and then impregnated with diazotroph cells in amounts of 20%, 5%, 20%, and 10%, respectively. It increases nitrogenous activity and survival rates.

Fluid Bed-Dried Formulation

A fresh method of producing such formulations that aid in sustainable agriculture is fluid bed dryer formulation. In this instance, a fluid bed dryer creates a fluidized environment where material is suspended against gravity and an upward air stream is present. Heat is provided for drying purposes by electrical heaters. The expansion of a bed of material that happens at terminal velocity as a result of this hot air's cause causes some type of turbulence inside a product, a process known as fluidization. The phenomenon causes a collection of solid particles, which causes continuous heat transmission and uniform drying. The use of a fluid bed dryer, which mostly finds use in companies that make processed food, has been suggested as a suitable drying technology for bio inoculants. This dryer has been used in several drying processes as well as the quick production of coffee powder. In this approach,

Biofertilizers

Granulation is often carried out in a closed process when it is moist. Because mixing and drying may be done in the same vessel while numerous components can be granulated, its application is extremely acceptable. It is a better candidate to be utilized in inoculant compositions since it requires less handling of the material and takes less time to complete the procedure. The formulation also goes through the following processes:

a. There is virtually little cell degeneration.
b. There is no contamination at any point in the process.
c. Several components are combined and dried.
d. Ambient temperature conditions are required for the drying process.

e. While the drying temperature may be adjusted in accordance with the specifications of the manufacturer.

A possible disadvantage in the formulation of Biofertilizers is the short shelf life and significant contamination of carrier-based inoculants. The product's effectiveness is also significantly hampered by the moisture content, which is a serious issue. The fluid bed drier, which is very effective for drying at 37°C–38°C, was launched as a result of improved Biofertilizer manufacturing techniques. Sensitive bacteria may have their temperature altered to be uniform. A particular water content was maintained throughout the drying process to reduce contaminant growth. Even while fluid bed drying is quite effective at making formulation, it is not currently functioning to produce bio inoculants. Although several studies have shown that they may include nitrogen fixers, microorganisms that promote plant growth, phosphate solubilizers, etc., they are not employed to produce inoculants because of their uses in food survival. To meet its protocols for usage in the Biofertilizer sector, further research is required.

Mycorrhizal Products

The AMF is a tried-and-true Biofertilizer that moves phosphorus from the soil into plant roots, giving the targeted plant a nutrient-rich environment. It has substantial value in the Biofertilizer sector due to the variety of hosts. Due to its bio trophic nature, mycorrhizal formation is difficult to produce on a large scale. This formulation was created utilizing a pot culture in which a host plant relationship had already taken place. Various mycorrhizae-based formulations are now employed for a variety of applications. Mycorrhizal spore production can be done in a lab setting for in vitro reasons, but it cannot be done on a wide scale. Due to a few special characteristics, such as its production under axenic culture, formulation's high shelf life and ease of handling, a strain developed that is superior to native fungi, and its economical production with high-quality inoculant formulations, arbuscular mycorrhizal fungi are potentially applicable on a variety of plants and are produced on a large scale.

It is achievable because to techniques like hydroponics and aeroponics. It is not, however, economically viable. Agrobacterium rhizogenes roots that have undergone genetic modification serve as a culture medium for mycorrhiza. The method is being used for bulk multiplication. The simplest method is a soil-based inoculum that grows AMF in the soil after the inoculant is created using a pot culture approach. Producing inoculants on-site may be done by improving the soil by developing mycorrhizae with the host. Peat-based inoculants are also known as the "nutrient film technique," which involves putting a host plant that has already been infected with fungus in a tray where nutrients flow in an oblique direction and adjusting pH. Blocks have peat in them. Additionally, the utilization of mixed bacterial inoculants with AMF is very advantageous in inoculant technology, where co-inoculation has positive benefits.

Stickers

Sticking agents are often used with peat-based materials, which improves the formulation's capacity to coat the seed completely. Particularly polysaccharides like carboxymethylcellulose or gum, caseinate salts, and polyalcohol derivatives are used by plants as sticky compounds. They need to have improved adhesion and microbial survival on seeds, be nontoxic, and be simple to disperse. In the case of rhizobia, sticking agents have been chosen to sustain bacterial viability, however it is yet unclear how viability is enhanced. The main problem of using them is that because of the seeds' enhanced stickiness, bacteria eventually contact with them.

Additives

Along with stickers, microbial strain, and transport material, inoculant composition also includes additional additives. Micronutrients, macronutrients, hormones, carbon or other mineral sources, and sometimes fungicides are among them. The provision of a nourishing and protecting environment is the primary goal of additions. Additionally, they boost the inoculant's quality by enhancing seed adhesion, product stabilization, toxin inactivation, strain survival under harsh environmental conditions, and even storage. Regarding cell survival, there is a significant relationship between the chemicals and strains. By retaining a large percentage of moisture that protects the cells from dehydration, compounds that resemble glycerol increase cell viability. There are several changes that must be made to strain in order to increase performance. The chemical makeup of the additive must stop it from degrading quickly. Various materials, including xanthan, clay, sodium alginate, and skim milk, have been investigated and the findings published.

Packaging

The kind of packing material has a significant impact on the quality of the vaccine. While preventing the exchange of moisture, it must yet let some oxygen to travel from inside to outside.

The substance must be packed with a sterile item. There aren't many materials that are better suited for autoclaves, but they're radiation sensitive and might get damaged. However, a flowchart that details the many processes in the process may be used to summarize the whole process of formulating Biofertilizers. It mainly demonstrates the selection of bacteria for inoculant formulation, the scaling up of beneficial strain production, the selection and sterilization of carrier material, and the usage of diverse materials such as stickers and other additives. A vital phase in the process is choosing the packing materials. Following inoculant production, it is sent to the market before being utilized by farmers to increase crop productivity.

CONCLUSION

Biofertilizers are a crucial component of the sustainable agriculture that has been embraced internationally to keep up with the expanding population and prepare it for the effects of climate change, food shortages, and degradation of agricultural land. Discussion of the whole formulation approach, particularly the kind of Biofertilizer formulations, was highlighted in this chapter. According to the targeted soil and the formulation's method of action, it discusses reported bacteria utilized in the process.

The advantages and disadvantages of various formulations, including powder formulations, granular formulations, liquid formulations, and cell encapsulation, were reviewed. In order to increase the effectiveness of the Biofertilizer, other additives and sticking agents were also applied.

Despite outstanding attempts to increase inoculant production efficiency, variance still falls short of the true potential. The longest shelf life, lowest contamination level, and highest microbial count are all goals that have been pursued. Additionally, additional formulation techniques are being researched in order to produce better Biofertilizers with larger yields. The challenge for Biofertilizers in the future is to create effective microbial inoculants that are more cost-effective, simple to handle, and more successful for sustainable agriculture. These inoculants should also have a greater microbial count, improved shelf life, and resilience to biotic and abiotic stress.

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CHAPTER 8

ANALYZING THE POTENTIAL OF TRANSGENIC MICROORGANISMS AS BIOFERTILIZERS FOR ENVIRONMENTAL SAFETY AND SUSTAINABLE AGRICULTURE

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ABSTRACT:

Biofertilizers are compounds created using various eco-friendly microorganisms to increase soil fertility and plant nutrient absorption. Chemical fertilizers with an inorganic basis are one of the methods now utilized to increase soil fertility. However, ongoing use of chemical fertilizers to manage soil fertility poses a serious risk to both human health and the environment. In this case, it is possible to increase crop output for sustainable farming by using advantageous microorganisms as bio-fertilizers. Application of Biofertilizers, a more affordable and sustainable source of plant nutrients than chemical fertilizers, is one of the key elements of integrated nutrient management. Depending on their ability to obtain various minerals and nutrients from soil and the atmosphere, different microorganisms are being utilized as Biofertilizers. Different types of helpful microorganisms that can solubilize potassium and phosphorus and fix atmospheric nitrogen are included as key components in organic Biofertilizers. Utilizing cutting-edge methods of genetic engineering to create Biofertilizers, modern biotechnology encourages the evolution of new strains of genetically altered or transgenic microorganisms. It might be possible to create new environmentally acceptable Biofertilizers for sustainable agriculture by using genetically modified bacteria as fertilizers.

KEYWORDS:

Biofertilizers, Inorganic Fertilizers, Modified Organisms,Microorganisms, Nutrients, PGPR, Sustainable Agriculture.

INTRODUCTION

The adoption of strong and sustainable farming techniques to protect natural resources and simultaneously increase in growth and output are two key problems during agricultural operations as the world's population is predicted to increase and reach 9 billion by the year 2050. Agriculture techniques must be comprehensive and sustainable in order to meet the demands of a population that is constantly expanding. However, it is abundantly evident that agricultural output cannot be increased unless the nutrients the crop production uses up in the soil are replaced. Due to a lack of sufficient quantities of essential nutrients, the majority of agricultural soils are unable to sustain optimum levels of plant development. Farmers typically use chemical-based fertilizers to combat this problem and increase yield. The majority of nations have seen an improvement in grain output since the 1960s because to the use of these inorganic fertilizers, but their long-term continuous use causes toxicity issues in plants owing to environmental pollution, which worsens human health.

Although these fertilizers promoted plant development, they should not be used to change the characteristics of the soil. It is evident that the intensive cropping system's crop output and soil fertility have decreased as a result of the excessive use of inorganic chemical-based fertilizers with high levels of nitrogenous, potassic, and phosphorous. In addition, farmers in emerging nations with limited incomes cannot afford to spend additional money on costly chemical fertilizers. Therefore, producing enough food in a sustainable manner is one of humanity's toughest issues going forward. This opened the way for consolidative control of plant nutrients. Therefore, in this case, innovative farming techniques that use biological fertilizer as a source of nutrients are required to increase crop output with little environmental damage.

In the biogeochemical cycles that govern the recirculation of elements on our planet, soil-dwelling microorganisms are essential. In their capacity as producers, plants create biomass via photosynthesis, and the byproducts of that process are partially released into the soil through root exudates or the deterioration of plant matter. This ongoing process results in an accumulation of organic materials in the soil, which different heterotrophs might use as a substrate. Since the beginning of evolution, many bacteria have been found to help plants develop, and these plant/microbe relationships have been shown to provide mutual benefit for both cooperating species. The majority of these symbiotic bacteria reside in the rhizosphere, or the part of the soil directly impacted by root secretions. As a result, realistically speaking, this group of organisms may play a key role in enhancing plant development and ensuring abundant food supply via a sustainable approach, which would reduce the need for chemical fertilizers, whose manufacturing depends on non-renewable sources of energy. Taking into consideration all of these benefits, replacing inorganic chemical fertilizers with Biofertilizers is the greatest tactic to increase the sustainable production of crops without causing any ecological issues[1].

A Biofertilizer is a substance applied to the soil in composting areas with the goal of increasing the number of microbes to improve the nutrients' availability to plants for simple assimilation. It is made up of live or dormant cells of competent microbial strains obtained from plants' rhizospheres that are capable of fixing atmospheric nitrogen, solubilizing phosphates, and hydrolyzing cellulose. It was shown that bacteria in the bio-fertilizers speed up the delivery of the necessary nutrients by inducing a variety of processes that encourage plant development and ensure sustainable output. In order to increase agricultural output, using Biofertilizers and natural manure sometimes requires a minor financial outlay for environmental reasons. Thus, in order to meet the growing demand for safe and nutritious food, maintain sustainability, and address rising environmental degradation brought on by increased use of agrochemicals, organic farming has emerged as a major focus issue.

DISCUSSION

Carbon, hydrogen, and oxygen are typically plants' three main chemical components. In addition to these, nitrogen is a crucial element that plants need in large amounts to control the buildup of organic matter. The atmosphere of the earth contains a lot of nitrogen, which is also very inert. It may be found in proteins, amino acids, and a number of other organic substances that are created during the nitrogen fixation process. Even though it is abundant in nature, only a small number of animals and plants that are engaged in symbiotic or non-symbiotic partnerships may access it. The productivity of plants will decrease as a result of this circumstance. According to research, free-living, active microorganisms that fix nitrogen are crucial for the growth and development of plants. About 70%, or 175 million metric tons, of atmospheric nitrogen is fixed by the biological nitro-gen fixation process, and the remaining fraction is finished by either autotrophs or heterotrophs. Biological nitrogen fixation is an essential function of the bacteria. Modulated legumes were expected to have a significant role in converting 65% of the total nitrogen via microbial processes. Different plant-microbial interactions, such as symbiotic relationships between bacteria and plants, symbiotic interactions between blue-green algae or cyanobacteria and plants or fungi, and free living auto or heterotrophic bacteria that frequently associate with detritus or soil, preclude the conversion of nitrogen from its gaseous state to the form used by other organisms and plants.

Microbes Involved in Fixing Nitrogen

A well-known gram-negative nitrogen-fixing bacterium called azospirillum grows widely in the soil of subtropical, tropical, and temperate climates. It forms intimate associations with the roots of several agricultural and wild plant species. By accelerating root and shoot growth and speeding up the pace at which the roots absorb water and minerals, it immediately helps plants. Cyanobacteria are the next group of organisms crucial to the nitrogen cycle on a global scale. They are powerful nitrogen fixers in freshwater and marine habitats. Due to their ability to fix nitrogen and endurance to dehydration, cyanobacteria are now favoured for use as Biofertilizer in current agricultural methods since they can survive in harsh environmental circumstances.

Vitality of Phosphorus

Phosphorus, along with nitrogen, is one of the most important growth-promoting macronutrients required by plants for healthy development, particularly in tropical regions where soil phosphorus availability is low. Plant cells mostly take up H2PO4 or HPO24 forms of phosphate, depending on the pH of the soil. It makes up between 0.2% and 0.8% of a plant's dry weight and is believed to be essential for a variety of biochemical and physiological processes, including photosynthesis, root growth and development, stalk and stem strength, seed and flower formation, crop quality and maturity, energy production, cell growth and division, fixation of atmospheric nitrogen in legumes, and the development of disease resistance. In cereal and leguminous crops, an adequate amount of phosphorus promotes quicker maturity and optimal seed development. Primordia production in plants' reproductive organs requires this element in appropriate amounts throughout the plant's early developmental stages.

Although the readings of phosphorus in soil tests are often significantly higher, a significant portion of it is present in the form of insoluble phosphates such aluminum, calcium, and iron phosphates. As a result, the amount of soluble phosphorus is quite low, ranging from ppb in less fertile soils to 1 mg/ml in soil that has received heavy fertilization. Therefore, phosphorus shortage significantly reduces crop development and production. The bulk of phosphorus applied as chemical fertilizer to acidic and calcareous soils will be trapped there as metalcation complex precipitate, with long-lasting impacts such as reduced soil fertility, eutrophication, and increased environmental carbon footprint. Therefore, the levels of this element are low and inadequate in agricultural soil solutions to meet the needs of crop plants[2].

The Microbes That Solubilize Phosphate

Typically, soil is a universally beneficial, essential medium for the development of microbes, and the microorganisms that live there play a significant part in the dynamics of soil phosphate and control the phosphorus availability to plants as a result. Microbial systems can balance the needed phosphate demands of agricultural plants thanks to their effectiveness in solubilizing phosphate. Some rhizobia species, such as R. Melliotti, R. leguminosarum, as well as M. Brady rhizobium species, Mediterranean bacteria, and B. According to reports, japonicum solubilize phosphorus by releasing low molecular weight organic acids that interact with phosphorus' inorganic form. In barley and chick pea, a few species of rhizobia have been identified to be active in phosphate Solubilization. Numerous additional bacteria, fungi, and molds that have been isolated from soil have also been documented to solubilize the organic and inorganic phosphates that are present there.

PSM microorganisms have the ability to hydrolyze both inorganic and organic forms of phosphate molecules from insoluble substances. These PSM were reportedly metabolically active in the rhizosphere of the plants where they were discovered. In the group of PSM, many strains of organisms from gen-eras of bacteria, genera of fungus, arbuscular mycorrhizal, and actinomycetes are noticeable. Bacteria and fungi that hydrolyze phosphorus make about 1%-50% and 0.1%-0.5% of the total population of microorganisms in soil, respectively.

Along with the aforementioned species, rhizobia that fix nitrogen in symbiotic relationships and the nematofungus Arthrobotrys oligospora were also shown to exhibit phosphate Solubilization activity. PSMs use a variety of strategies, including as lowering the pH of the soil, mineralization, and chelation, to solubilize phosphorus.

Decrease in Soil pH

Microbes use a variety of organic acids, including lactic, citric, 2-ketogluconic, gluconic, acetic, oxalic, malic, glyconic, fumaric, tartaric, succinic, glutaric, malonic, butyric, propionic, adipic, and glyoxalicacids, to reduce the pH of the soil throughout this process. Out of these, the microbial phosphate Solubilization process mostly produces the organic acids gluconic acid and 2-ketogluconic acid.

Mineralization

Microbes from animal waste, which is a primary source of organic phosphate, transform it into useable form via this process. Through the process of mineralization, PSMs convert organic phosphate into a form that can be used, and this happens in the soil at the expense of plant and animal remains, which are rich in organic phosphorus compounds like nucleic acids, phospholipids, sugar phosphates, phytic acid, polyphosphates, and phosphonates. PSMs hydrolize organic phosphate into inorganic phosphate by the enzymatic activity of acid or alkaline phosphatases, which is then immobilized by soil-dwelling plants.

Following fungi are few exam-ples observed to release phytases in mineralization process: Aspergillus fumigates, Aspergillus candidus, Aspergillus niger, Aspergillus rugulosus, Aspergillus parasiticus, Aspergillus terreus, Penicillium simplicissimum, Penicillium rubrum, Pseudeurotium zonatum, Trichoderma viride, and Trichoderma harzianum. Along with the previously mentioned bacteria, Streptomyces spp. Additionally, through secreting a number of extracellular enzymes such phospholipases, phosphodiesterases, phytases, and phosphoesterases, soil Bacillus hydrolyzes complicated forms of organic phosphate into simple inorganic. According to earlier research, using PSM mixed cultures is a successful method for the mineralization process.

Chelation

The cations linked to the phosphate group are chelated by the carboxyl and hydroxyl groups of inorganic and organic acids generated by PSMs, turning the insoluble form of phosphate into soluble form.

PSMs' Promotion of Plant Growth

A group of microorganisms that solubilize phosphate has the power to restore the fertility of degraded and unproductive soils for agricultural use. Application of this specific group was noted to

Biofertilizers

The addition of microorganisms to the soil facilitates simple phosphorus absorption from a wide region by creating a long network surrounding the roots, increases hydrolyzation of both fixed and applied soil phosphates, and ensures higher crop output. Due to their nature, these organisms had notable results whether utilized alone or in conjunction with other bacteria in the rhizosphere in traditional agricultural practice. PSMs inoculation and other plant parameters, such as biomass output, height, and phosphorus content, were shown to be clearly correlated. Increased crop yields were seen when soil was infused with bacteria such as Achromobacter, Agrobacterium, Bacillus, Erwinia, Flavobacterium, Micrococcus, Pseudomonas, and Rhizobium that can solubilize phos-phate. By creating plant growth regulators like cytokinins, auxins, and gibberellins and increasing the availability of several other trace elements like siderophore, phosphate solubilizing bacteria assure greater plant development. By using bioinoculation techniques, they also assist in enhancing nitrogen fixation efficiency. Afzal said that in the instance of Pseudomonas sp. Production of phytohormones is correlated with phosphate Solubilization in both and Rhizobium leguminosarum.

Method for Using PSMs as Biofertilizers and Looking Ahead

Utilizing microorganisms that solubilize phosphate as Biofertilizers to improve agriculture has been a focus of research for a long time. PSM inoculation may improve the soil's ability to provide phosphorus, and there is evidence of their benefits in the hydration of inorganic and mineral phosphates. These organisms were said to increase phosphorus absorption and increase crop output [3].

In this context, PSMs have used inoculations of Azotobacter and Bacillus to boost the production of wheat and sugar cane by up to 30% and 43%, respectively. Penicillium bilaii strain is used to create the commercially available inoculum of PSMs known as JumpStart. Additionally, the possibility for using organisms like Pseudomonas striata, Bacillus subtilus, Bacillus megaterium, and Bacillus circulans as Biofertilizers was shown. Therefore, PSMs are crucial in replacing inorganic phosphate fertilizers and boosting production by reducing phosphate demands via environmentally friendly agricultural methods. Therefore, it is important to research persuading bio-fertilizers with a variety of thrilling growth qualities.

Potassium's Importance

Potassium is one of the fundamental nutrients that is crucial for plant growth, development, and metabolism in addition to nitrogen and phosphorus. Additionally, this element is essential for the activation of enzymes that control various plant processes like photosynthesis, sugar degradation, starch synthesis, nitrate reduction, and other metabolic activities. It also plays a significant role in improving the resistance of plants to both biotic and abiotic stresses.

Although the amount of potassium in the soil is significant, only plants can access around 1% to 2% of it, and the rest portion is unavailable because of its interaction with other minerals. This element may be found in soil in a number of different forms, including exchangeable K, non-exchangeable K, solution K, and mineral K. Depending on the soil type, the bulk of this element is present as mineral K, which is inaccessible to plants, and just 1%–10% of it is present as non-exchangeable K, which is trapped between certain kinds of earth's mineral sheets or layers. The next form of K is solution K, which may be found in agricultural soils at concentrations of 2 to 5 mg L1, is readily absorbed by microorganisms and plants, and is regularly leached. The potassium levels in soil are quickly declining as a consequence of the introduction of new high yielding cultivars and ongoing agricultural development. Significant amounts of potassium are present in the soil in fixed forms as a result of uneven fertilizer usage in an effort to increase production, which ultimately causes the soil to be deficient in potassium, which has been seen in the majority of crops. It is essential to find an alternative and natural potassium source in order to maintain the levels of K needed for plant growth due to the growing costs of potassium fertilizers and their detrimental effects on the environment[4].

Bacteria Involved in the Hydrolysis of Potassium

It has been shown that the population of microorganisms in soil may control its fertility via a variety of activities, including mineralization, decomposition, and nutrient deposition. It became clear that a small number of helpful microorganisms, including a variety of fungi, saprophytic bacteria, and actinomycetes that live in soil, may hydrolyze insoluble forms of potassium via a variety of processes. The bacteria that solubilize potassium in these microorganisms have attracted the attention of agricultural experts as a very effective soil inoculum for enhancing the development and productivity of crop plants. These KSB are successful at releasing

Biofertilizers

The potassium from soil-based inorganic potassium reserves that have become soluble. These organisms are found in a variety of soil types, including non-rhizosphere soil, paddy soil, rhizosphere soil, and saline soils. Rhizosphere soils contain substantially more of these organisms than non-rhizosphere soils. Many bacteria, including B, are capable of mobilizing or solvating potassium. Edwardicus, B. mucilaginosus, circulans, Burkholderia, Pseudomonas, Acidithiobacillus ferrooxidans, and Paenibacillus species. Numerous soil bacteria, including B. The circulanscan, B. in addition to B. mucilaginosus were noted as being effective K solubilizers.

KSB's impact on plant development and yield

KSB was previously said to have a growth-enhancing impact on a variety of plants. Under field and greenhouse conditions, seedlings and seeds of different plants exposed to potassium solubilizing bacteria showed a noticeably improved percentage of germination, vigor of seedlings, growth and yield of plants, and potassium absorption. It was discovered that tomato plants B-vaccinated. Compared to control plants, the biomass of the mucilaginosus strain RCBC13 and its absorption of potassium and phosphorus increased by more than 125% and 150%, respectively. Similar results were seen in WH711 variety of wheat plants, where treatment with HWP47 strain of K-solubilizing bacteria led to gains of 51.46% in root dry weight and 44.28% in shoot dry weight. Aside from these, KSB also showed promising results in the growth and production of several crops, including tomato, okra, black pepper, potato, peanut, pepper and cucumber, rape, and cotton. The aforementioned studies show that KSB may be used as bio-fertilizers to increase agricultural yields while reducing the use of chemical fertilizers and cultivating land in an environmentally friendly manner. Therefore, the quick preservation of current resources and avoidance of environmental hazards brought on by excessive potassium fertilizer usage may be achieved by isolating competent strains of bacteria effective in potassium Solubilization.

Qualifications and Disagreements with K Solubilizing Bacteria

In order to improve plant nutrition, attempts have been made to make microorganisms available that hydrolyze potassium from a variety of mineral sources. Although KSB is another potential technology that can convert potassium from an insoluble form into a soluble form, its application in agricultural practice is limited due to a number of factors. For instance, farmers are not aware of the application of Biofertilizers, the gradual effect of potassium Biofertilizer on crop yield, researchers are less concerned with improving Biofertilizers, and KSB culture collection banks were not ready due to a lack of KSB. These are a few issues that must be resolved in the future to increase the value of KSB as Biofertilizers[5].Therefore, a sizable number of fungus or molds, along with certain bacteria, are reported to function as nitrogen fixers and potassium and phosphate solubilizers. These organisms may be combined with other types of microbes in a variety of combinations to make Biofertilizers. These Biofertilizers, which are important components of organic farming, play a crucial role in maintaining the sustainability and fertility of soil for an extended period of time and minimizing land degradation and concurrently enhancing crop output.

Arbuscular Mycorrhizae fungi, which invade plant roots, have emerged as one of the most important components of healthy plant-soil coordination systems. They can accelerate plant growth and development by encouraging the uptake of various nutrients like micronutrients, nitrogen, and phosphorus; by increasing photosynthesis and fruit yield; by energizing factors that affect growth; by maintaining osmotic regulation in salt and drought conditions; and by acting as antagonists against plant pathogens that cause disease. They can also help with improving pest tolerance. These types of mycorrhiza are not found on substrates without soil, according to previous research. By making nutrients and other necessary elements easier to reach in inoculated soils than in non-inoculated soils, mycorrhizal treatment reduces the demand for fertilizer.

Rhizobacteria that Promote Plant Growth

By improving plant development, yield, and seed availability, they may improve the ability of plants to flourish. Only a few number of PGPR induce systemic resistance to bacteria, fungi, viruses, and, in certain circumstances, nematodes. As PGPR strains, Bacillus or Pseudomonas species are most often utilized.

Biotechnology's Place in the Agricultural Sector

With ways to develop several new crop types with improved yields, increased nutritional content, and the ability to live in challenging environments with the least amount of pesticides and fertilizers needed, biotechnology has started to change agriculture. Genetically modified organisms, sometimes known as GMOs, are living things whose genomes have undergone changes or transformations to create transgenic organisms with desired traits by genetic recombination. Modern scientific methods, particularly genetic engineering, make it possible to achieve the best characteristics in organisms by incorporating a particular gene of interest. This results in the creation of powerful microbial strains and new crops with novel traits like pathogen, pest, and herbicide resistance. Currently, biotechnology is supplying cutting-edge solutions in the form of Biofertilizers for the welfare of society when there are no other alternative strategies due to restrictions on the use of inorganic-based chemical fertilizers and pesticides due to their environmental problems. Additionally, various microbe strains that can delay the onset of disease and promote plant growth seem to restrict the use of fungicides, pesticides, and fertilizers and open up new avenues to prevent significant crop yield losses that are insurmountable even with today's agrochemicals. Therefore, it is envisioned that biotechnology may function as a trustworthy source to attain sustainable food production in a way that is kind to the environment[6].

The majority of inorganic fertilizers used today are produced industrially by the Haber-Bosch method, which is authorized in industrialized nations that can afford its cost but prohibited in developing nations because such costs are unaffordable. In addition, fossil fuels are used during this process to create ammonia from nitrogen gas, which consumes around 5% of the entire natural gas generated globally. Therefore, compared to fertilizers made by the Haber-Bosch process, the usage of in situ mode of functioning transgenic diazotrophs created via genetic engineering through gene modification should lessen concerns with environmental contamination. Additionally, they allow the fast release of nutrients during plant growth and improve nutrient digestion, which may solve current issues with agricultural waste discharge.

The underlying mechanisms essential for microbially induced plant growth and development are still in the early stages and need to be understood at multiple molecular levels. This knowledge was used to modify the genetic makeup of microbial strains in order to enhance them via genetic engineering. There are numerous instances where significant progress has been made in utilizing the potential of microorganisms as plant growth inducers, including the transformation of PGPB strains with the 1-aminocyclopropane-1-carboxylate deaminase gene to lower the levels of ethylene in plants, the development of microbial strains secreting higher levels of IAA, and strains of microbes changed genetically to produce fixed form of ammonium. A research perspective of the processes causing the plant development is required for the environmental safety assessment of the administration of corresponding strains. For instance, it has been suggested to transmit ACC deaminase genes laterally in rhizospheric bacteria.

Biofertilizers and Phytostimulants

Bradyrhizobium, Sinorhizobium, and Rhizobium are a few examples of several bacterial species that are employed as Biofertilizers to promote plant growth and development. They create symbiotic relationships with leguminous plants and provide the host with readily available nitrogen. By genetically altering microorganisms as part of the IMPACT program, Biofertilizers have been created that are effective at forming symbiotic relationships with host plants and reducing the need for fertilizer application. Azospirillum may be thought of as one of the phytostimulators that promotes plant development by producing chemicals that heighten root growth and permit increased absorption of nitrogen and water. In order to increase agricultural productivity and save the environment from harmful chemical fertilizers, strains that can generate high quantities of growth-stimulating substances have been created using genetic engineering. In the IMPACT initiative, the effect of genetically engineered phytostimulators and Biofertilizers on the population of naturally occurring microorganisms was assessed along with their effectiveness in increasing agricultural output[7].

Other than carbon dioxide, plants take the bulk of their nutrients from the soil, which, in accordance with the current policy of sustainable agricultural practice, has to be improved with nutrients derived from renewable sources. Leguminaceae plants' biological nitrogen fixation process, which prevents massive amounts of nitrogen from being released into surface water bodies, is a great example to use to illustrate this idea. Nitrogen-fixing bacteria may be investigated as a self-replicating source of nitrogen for plants since, despite their abundance on roots, not all plants can establish symbiotic relationships with these bacteria. Agriculture production depends mostly on inorganic sources of fertilizers until sophisticated techniques are developed to encourage symbiotic relationships between the microorganisms engaged in nitrogen fixation and the crops of agronomic value. Fertilizers are supplied to soil as nitrate, which is highly mobile in nature, to supplement the nitrogen level. As a result, more nitrogen is provided to the soil than is required to promote perfect plant growth. Currently, to improve yield, rice fields consume around 450 kg of nitrogen per hectare, of which only 200–250 kg is used for plant development. Therefore, more than half of the nitrogen supplied seeps into the environment, having a negative impact on the atmosphere.

Different strategies to increase the uptake of fertilizer by roots have been developed, including the use of PGPR and alternate fertilizer formulations including controlled and delayed release fertilizers. These PGPR either directly influence plant growth or indirectly do so by acting as biocontrol agents to get rid of harmful diseases and microbes.

These achievements have been put to use in a study program that involves creating bacteria, evaluating different physiological processes, and conducting a final test in the field. There are at least three routes that seem to be involved in the intricate process of IAA biosynthesis carried out by strains of Azospirillum. By manipulating the gene ipdC, which is in charge of expressing a crucial enzyme in the indole-3-pyruvic pathway, Azospirillum was able to produce more IAA. These strains were created with certain genes acting as markers to make it possible to find them during field trials in the soil. The two genes chosen as marker genes are gfp and lue; gfp codes for green fluorescent protein, which causes a cell to fluoresce, while lue expression results in bioluminescence, which causes bacteria-containing cells to light[8].

Currently, Azospirillum strains come in basic varieties. However, thorough and reliable experimental analysis carried out in a controlled environment is required before they are made available for field trials. Studies in IMPACT nowadays are focusing on the impact of genetically modified Azospirillum strains on the native microbial population, the pace at which plants absorb nitrogen from the soil, and the rate at which plants grow. These tests are conducted in a glass house and growing cabinets to learn crucial information about how GM strains behave in real-world settings. The international collaboration of the IMPACT consortium facilitates the conduct of research involving diverse crop categories in various soil types under varying climatic circumstances.

Genetically Modified Rhizobium Strain Development with Enhanced Competitiveness. By introducing more capable nitrogen-fixing bacteria to inoculate the seeds, the production of leguminous plants like beans, peas, and clover may be increased. However, owing to the existence of native microorganisms with weak nitrogen-fixing capacities, inoculation of legumes is often ineffective. Biofertilizerschallenges with newly acquired or imported strains for nodule initiation. The ability to dominate nodulation is referred to as competitiveness, and it is very important for the potentially successful use of rhizobial bacteria as inoculants.It is thus advised to change the strain employed as the inoculant to ensure that it should occupy a sufficient number of root nodules to support enhanced levels of nitrogen fixation for the host plant[9].

It has been shown that genetic modification may boost the nodulation competitiveness of distinct Sinorhizobium meliloti bacterial strains acquired from different geographical locations. This genetic modification also affects the expression of the nifA gene, which is crucial for controlling the activity of all the genes involved in nitrogen fixing. In mixed inoculation trials, it was shown that genetically modified strains of S. meliloti inhabited the majority of root nodules in alfalfa roots compared to wild type. Although the genetic basis for this development is not fully understood, it has been proposed that the gene nifA controls the expression of genes other than nif genes. It was hypothesized that changed gene expression would encourage and facilitate the establishment of root nodules. The ability of rhizobium bacterial strains to accurately detect the plant root is another factor critical in nodulation competitiveness in addition to gene expression. It has been hypothesized that using enthralled microbes as inoculants

CONCLUSION

The emission of CO_2 from uninoculated plants seems to be noticeably lower in nonrhizosphere soil than in rhizosphere soil. Compared to plants inoculated in the rhizosphere region of the soil, nonrhizosphere soil showed a lower rate of respiration. Additionally, the amounts of CO2 generated in soil inoculated with non-GM and GM strains are comparable. These studies suggest that although the presence of plants has a significant impact on the mineralization of carbon in the soil, the effects of genetically modified Rhizobium strains is negligible compared to the wild-type strain. In terms of N2O generation, soil devoid of plants had an emission strategy that was quite different from soil containing plants. However, there was no difference in the generation of N2O between non-GM and GM strains or between uninoculated and inoculated plants. These findings support those of CO2 generation and suggest that, when compared to wild-type strains, the plant's impact on microbial activity is noticeably greater than that of genetically modified microbial inoculants.

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CHAPTER 9

BIOFERTILIZER UTILIZATION IN AGRICULTURAL SECTOR

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ABSTRACT:

In order to enhance agricultural productivity, it has been shown that the current agricultural techniques significantly rely on the use of synthetic inputs. When used in excess, these synthetic compounds have been shown to have a number of negative impacts, most notably health and environmental risks and excessive levels of pesticide residue on agricultural goods. Additionally, this has caused an increase in the building of heavy metals in the soil as well as these pesticides with detrimental effects on the soil. These chemical fertilizers have been shown to include acid radicals, such as sulfuric and hydrochloride radicals, which have increased soil acidity and negatively impacted the health of the soil and plants. In order to avoid all the issues with synthetic fertilizer that have been highlighted, it is necessary to search for a sustainable, dependable, biocompatible, and environmentally friendly fertilizer. It has been discovered that using microorganisms as Biofertilizers is a sustainable strategy that might improve or result in an increase in agricultural production. As a result, the purpose of this chapter is to provide comprehensive information on the use of Biofertilizer as a sustainable biotechnological instrument that might boost agricultural productivity. Specific instances of how Biofertilizer has been used to boost agricultural productivity were also highlighted, along with detailed information on the mechanisms of action of these fertilizers. Additionally discussed were recent developments in the use of microbial inoculum as a sustainable technique that might enhance plant health.

KEYWORDS:

Agricultural, Biofertilizer, Biocompatible, Environmental, Hazards, Eco-Friendly.

INTRODUCTION

Increasing agricultural production is important to fulfill the expanding global food demand. This is particularly concerning since there isn't enough land available for agricultural growing, forcing farmers to continuously cultivate their property. Farmlands that are continuously tilled may lose all or part of their soil fertility. Farmers decide to use inorganic fertilizer to get around this problem and maintain or increase agricultural yields, however unchecked and continual usage of inorganic fertilizer is bad for the ecosystem. As a consequence of runoff from non-point source pollution, the nitrogen and phosphorus from fertilizer may enhance water bodies when it is washed off the applied soil. When too much of a nutrient is present in a body of water, it may lead to eutrophication, particularly if the water is still. In place of using inorganic fertilizers, organic manure has been used[1].

Its usage has drawn considerable criticism due to its bulky size and the possibility that some of it contains pathogenic organisms that might be damaging to plants. Biotechnological advancements have discovered several microbial species that can enrich the soil either independently or in connection with their roots in order to overcome the aforementioned difficulties. A Biofertilizer is a product that contains active or latent cells that is administered to soil or plants. After application, the Biofertilizer colonizes the rhizosphere of the plant. The plant's access to nutrients is increased as a consequence of this invasion. Biofertilizers employ a variety of methods, including as fixing atmospheric nitrogen, phosphate Solubilization, and increasing soil synthesis of chemicals that encourage plant development, to provide nutrients to the plants. Using Biofertilizer as a bio augmentation agent in heavily polluted soil bioremediation. Environmental biotechnologists have long discussed the idea of bio augmentation, which is introducing microbial inoculants into a contaminated environment in order to speed up the bioremediation process. It is often utilized in contaminated environments where native microflora restoration is sluggish or challenging. A number of studies have shown that applying Biofertilizer to polluted soil has had positive outcomes.

The biochemical composite material used in a pot experiment to remediate cadmium has the bioremediation capacity of biochar and plant growth-promoting bacterium, Bacillus sp. TZ5. Their findings demonstrated that the bacteria-added biochar was more effective at immobilizing cadmium than unaffected biochar. In soil containing biochar-bacteria composite, their research also shown an increase in soil microbial enzyme activity. As a result, the research came to the conclusion that BC-TZ5 composite was an excellent supplier of nutrients and effectively cleaned up the soil. Azobacter was discovered from mercury-contaminated soil by Hindersah et al. They hypothesized that employing Azobacter to bioaugmentation heavy metal-contaminated soil is a renewable biological method that is simple, affordable, and secure.

Using two nitrogen-fixing bacteria and phosphate-solubilizing bacteria that were identified by 16sRNA gene sequence analysis, the ecorestoration of soil that has been polluted by crude oil. Both of the two bacterial groupings were employed separately and together. For 4 weeks, the microcosm research experiment with bioremediation was under observation. Their findings showed that the effectiveness of total petroleum hydrocarbon reduction was 97.8% for NFB and 94.3% for PSB, respectively, as opposed to 92.1% and 34.6% for NPK and control, respectively. The elimination capacity seen with NFB and PSB, according to these scientists, is proof that nitrogen and phosphorus are important limiting variables during bioremediation of crude oil.

Their research showed that nitrogen-fixing bacteria, among other modified microbes, could play a significant role in nitrogen fixation and cometabolism to autochthonous bacteria, which aid in the absorption of crucial nitrogen and could facilitate the degradation of hydrocarbons. Additionally, it shown that phosphorus is necessary for bacteria to use during bioremediation. The capacity of heavy metal-contaminated soil's plant growth-promoting bacteria to clean up mercury and arsenic-contaminated soil. According to their findings, the thirteen indigenous bacteria strains have a lot of promise for accelerating the bioremediation of heavy metals. This was shown by both their strong expression of plant growth-promoting abilities and their tolerance to high concentrations of the heavy metal.

Jiao et al. have proved the bio augmentation capacity of Rhodobacter sphaeroides Biofertilizer in a soil polluted with petroleum. These scientists said that employing a combination of three plant species wheat, cabbage, and spinach after 120 days. They discovered the following values for the wheat, cabbage, and spinach rhizospheres, respectively, for the removal of TPH from contaminated soil in the Rhodobacter sphaeroides Biofertilizer bio-augmented rhizosphere soils.

DISCUSSION

Based on their roles or functions in soil processes and plant physiology, Biofertilizers have benefits over chemical/synthetic or conventional fertilizers. Originally, chemical fertilizers provided plants with easy access to three essential nutrients: NPK for growth and development. A more enriched, inexpensive, and environmentally friendly form that is rich in plant-beneficial microbes and organic matter as well as NPK makes it superior to the conventional type for farming purposes despite their expensive nature and lack of ability to provide other essential plant nutrients.

The overuse of commercial chemical fertilizers for agricultural purposes has increased the influence on soil processes, which has an impact on how nutrients are transported between the soil's constituents and the plants. Farmers and producers need a viable option to reduce and counteract these effects. Accordingly, Carvajal-Muoz and Garcareviewed the benefits and drawbacks of using Biofertilizers instead of chemical fertilizers in agriculture. In light of the present situation of population expulsions, the authors indicated that food processing and supply need to be improved. Biofertilizers must be applied to plants in order to accelerate the development and expansion of agricultural output in order to satisfy this demand. They claimed that Biofertilizers offer numerous advantages over commonly used fertilizers, including the ability to be applied without expert help, the ability to provide superior quality both during and after harvest, the ability to increase event efficiency at a very low cost, and more economic viability [2].

Utilization of Biofertilizers in Agriculture

Compared to the conventional kinds, they have little to no environmental invasion. According to the authors, Biofertilizers have taken the place of chemical fertilizers as a cutting-edge technology that may be utilized to lessen the effects that the latter have on rural ecosystems. Some of the current generations' efficiency-based constraints were emphasized. In a review, Ajmal et al. examined the use of Biofertilizers in place of traditional fertilizers in agricultural. According to the authors, the agriculture industry plays a significant role in the makeup of the human population in the effort to bring about a "green revolution." That biotechnology is essential to the creation of bio pesticides and Biofertilizers as a sustainable alternative to chemical fertilizers, which have the potential to negatively impact soil, water, and air quality.

They said that Biofertilizers have high nutritional levels and include microorganisms like rhizobacteria that aid in the soil's capacity to absorb nitrates for usage by plants. In addition, by using a carrier material on which the microbe is straddled, Biofertilizers also improve the effectiveness of conventional fertilizers. Products from these biochemical fertilizers have a shelf life of between six months and two years in both the liquid and solid phases, and they may also be used as fish feed. In their conclusion, the authors noted that in addition to the enormous advantages associated with the use of Biofertilizers, there are some restrictions on their application. For example, manufacturers may experience difficulties during production, and there may be a potential health risk due to unexpected exposure to pollutants like heavy metals. Pesticides and Biofertilizers might be a solution to the contamination issue that conventional fertilizers are facing if these issues can be avoided.

Fertilizers, particularly chemical fertilizers, play a crucial role in the process of increasing agricultural production and quality. However, its widespread usage heralds tremendous hazard for human health, plant physiology, and soil function. A sustainable and eco-friendly solution is desperately required to address this issue. On this basis, Ye et al. studied and assessed the possibility of switching from chemical fertilizers to organic fertilizers in order to improve soil fertility and tomato production quality. In a field environment, four treatments CF as the control, TSS, OF, and BF were used on tomato plants with an amalgam of bio-organic fertilizers with Trichoderm sp. According to their study's findings, tomato plants treated with bioorganic fertilizer accumulated more nitrate, vitamin C, and soluble sugar than untreated plants in the proportions of 62, 57, and 24 correspondingly. The outcomes of the field and pot studies revealed a decline in the percentage of Biofertilizers on tomatoes, bioorganic and chemical fertilizers produced yields that were comparable to those of chemical fertilizers used alone. However, it was shown that using Trichoderma spore suspension in conjunction with organic fertilizer resulted in a lower yield than the control. The level of soil microflora subsequently increased, and the enhanced soil fruitfulness also showed a good direct correlation, particularly in the Biofertilizer treated soils. The efficacy of bioorganic fertilizers for maintaining a balance in tomato production and improving their quality, according to the authors' opinion, was a result of soil and microorganism activity. As a result of their research, the authors proposed combining Trichoderma bioorganic fertilizer with certain conventional chemicals to maximize crop benefit and create a sustainable agricultural tool for the future.

Based on its synergy with nature, organic farming, according to the authors, makes the agricultural system sustainable for both current and future users. The restoration of the soil ecosystem is necessary for both biotic and abiotic function. Additionally, they recalled that Biofertilizers play a significant role in preserving soil fertility and the maintenance of its nitrogen content. They do this by assembling micro- and macronutrients and converting soil phosphate into forms that are bioavailable to plants, thereby increasing their availability and effectiveness. Because of the harm it will do to soil, soil microfauna, and people at the top of the food chain, the scientists concluded that Biofertilizers are a more promising tool for sustainable agriculture than chemical ones. More specifically, the association of the mycorrhizal found in the Biofertilizer and soil increases the perfect soil function and productivity/area, improving the soil structure, increasing nutrient uptake through an increase in the nitrogen and phosphate level, and reducing soil and plant toxicity by producing Glomulin, a protein component. They identified a breakthrough in the biotechnology field of Biofertilizers, a novel liquid Biofertilizer that has been shown to be more successful than the traditional Biofertilizer. In order to prevent a better agricultural reinforced system of efficient production of appropriate yields, the authors concluded that this unique Biofertilizers should be broadly embraced by commercial Biofertilizer manufacturers, extension workers, as well as the farmers.

Overpopulation is one of the biggest dangers to the security and safety of our food supply. Land may become overpopulated, making farming operations difficult. Consequently, it is imperative to invest in sustainable organic farming in order to feed the world's growing population utilizing efficient biotechnological strategies. In light of this, Mahanty et al. examined a potential technique for sustainable farming employing Biofertilizers in a review. They claimed that the excessive use of chemical fertilizers in recent years has had a detrimental influence on the agroecosystem’s biota and land usage in addition to increasing crop productivity. However, using Biofertilizers for efficient and sustainable agriculture is the way ahead. Fungus, bacteria, and cyanobacteria have all been shown to support plant growth and the creation of vital components. Additionally, they said that research has shown that Biofertilizers have the capacity to provide plants with tremendous amounts of nutrients, which may increase agricultural productivity. The mechanisms of action for employing Biofertilizers to stimulate both plant growth and development were studied. The importance of Biofertilizers in a number of fields, including ecology and bioremediation, was also highlighted.

In the agroecosystem, fertilizers, herbicides, and pesticides have all been shown to have detrimental effects when used excessively or in the improper quantities. Acidity levels in the soil and crop physiology are severely impacted by chemical components such radicals from sulfuric and HCL acids included in synthetic fertilizers. Alori and Babalola conducted a review of the usage of microbe-based inoculants in boosting agricultural value and human health. According to the authors, these inoculants operate as messengers for biocontrol, bio pesticides, bio herbicides, and Biofertilizers, which are all utilized to increase plant growth, health, and production as well as control weeds, disease, and pests. They said that the microbe inoculants, which comprise different strains of bacteria, fungus, and algae, are affordable, easy to use, and favorable to the environment.

Biotic and Abiotic Stress Management

In order to improve crop fruitfulness, tolerance, and yield, Bhardwaj et al. conducted a study of the potential signature of Biofertilizer as sustainable farming practice. They said that chemical fertilizers had caused significant issues with the ecology and health of soil, plants, and people. These have called for the use of innovative, affordable, non-harmful, and ecologically friendly agricultural methods like Biofertilizers in order to offer sustainable crop production and food security. The authors described a few of the beneficial microbes that are used as Biofertilizers, including cyanobacteria, ecto- and end mycorrhizal fungi, and PGRPs. These microbes help plants develop faster and more vigorously and increase nutrient intake. The authors also emphasized the Biofertilizers' facilitated position as functioning individuals in the activation of Biofertilizers hormones in plants, unique disease defenses, nutritional analysis, and so forth. They concluded by stating that the information gained from the use of Biofertilizers should be used to reducing the problems brought on by conventional fertilizers.

Agriculture using sustainable methods is popular nowadays. However, some ecological stresses have an impact on plant development and output. In a review, Selim and Zayed examined the sustain-able role of Biofertilizers in the control of ecological stresses in agriculture. They listed the strains that both living and non-living things place on plants as they struggle to survive. Humans, insects, plants, and pathogenic microorganisms are examples of living variables, whereas mineral nutrients, heavy metals, intense light, wind, varying temperatures, drought, waterlogging, and salt soil are examples of non-living forces. According to their analysis, climate change causes the majority of these non-living components, which might cause a reversal in agricultural productivity. Beneficial bacteria that predominate in plants' roots encourage the plant to react favorably to environmental stress. Different microbial strains, however, have varying tolerance levels. These microbes are added to fertilizers known as Biofertilizers, which can also fix and release siderophores for dinitrogen and iron in plants, increase nutrient contents by solubilizing phosphate, enable polysaccharides and water uptake in plant roots, and stimulate the production and growth of phytohormones in plants. The authors emphasized the value of employing microbial inoculants as next-generation Biofertilizers in their conclusion to help mitigate diverse ecological pressures[3].

Phaseolus vulgaris was experiencing water stress, and Chavoshi et al. examined and assessed the possible effects of Biofertilizers in resolving this issue in a field irrigation environment. In the biological test experiment, four subplot examples were used: KSB, PSB, control, and soil bacteria[4], [5]the results of the biological experiment demonstrated a substantial interaction between Biofertilizers and stop irrigation on Phaseolus vulgaris biomass as well as high biomass when PSB and KSB were administered, respectively. However, using Biofertilizers instead of chemical fertilizers led to improved water efficiency in environments with limited water supply. In the end, their experiment revealed a high bio of 7,985 kg/ha in the biotic management of Phaseolus vulgaris when sufficiently submerged. The usage of Bio-K and Bio-P fertilizers, which regulated and alleviated biomass decline to approximately 37%, was found by the authors to have increased cease watering during the blooming stage [6]–[8].

CONCLUSION

The practical use of Biofertilizer as a sustainable biotechnological instrument that might boost agricultural productivity has been thoroughly covered in this chapter. Specific instances of how Biofertilizer has been used to boost agricultural productivity were also highlighted, along with information on the mechanisms of action of these fertilizers. Additionally discussed were recent developments in the use of microbial inoculum as a sustainable technique that might enhance plant health. Increased output of Biofertilizer may result from the use of genetic engineering, synthetic biology, nanotechnology, and bioinformatics. Additionally, the use of whole genome and next generation sequencing will be essential in identifying major genes of interest that might create large levels of phosphorus and be essential in the soil's Solubilization of complex phosphorus.

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CHAPTER 10

A CRUCIAL SOURCE FOR SUSTAINABLE AGRICULTURE: AZOSPIRILLUM

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ABSTRACT:

The free-living, nitrogen-fixing bacterium species Azospirillum is the most researched among the rhizobacteria that aid in the development of plants. It stimulates plant growth in a variety of ways, each of which is controlled by a different mechanism. Comprehensive investigations are being conducted on the interaction of this microorganism with the plant root system since it is exceedingly intriguing. Its ability to survive in the bulk soil and rhizosphere is crucial for it to have the desired effects. Additionally, to its agricultural uses for sustainable growth, this organism demonstrates its usefulness in preventing the buildup of several dangerous compounds in plant roots. Its genetic structure should be further studied to better understand its molecular processes and broaden its scope of applicability. Azospirillum spp. should be used more extensively on a wide scale for commercial inoculants, therefore it would be ideal to have access to better production techniques, greater finance, expanded production awareness, and quality bio inoculant handling.

KEYWORDS:

Agriculture, Azospirillum,Bacterium Species, Food, Rhizosphere.

INTRODUCTION

According to research by the Food and Agricultural Organization, the world's population is growing exponentially and is expected to reach 8 billion people by 2025. This need an equal increase in world food production. Since the amount of arable land globally is decreasing due to rising population and urbanization rates, the predicted growth in global agricultural output must be controlled by a rise in food production on already arable land using cutting-edge methods. In order to boost food output, this further emphasizes the need on chemical fertilizers. The amount of chemical fertilizer use is anticipated to increase by 54.6% by 2030. However, this does not mean that the plants are absorbing more nutrients; in fact, a large portion of the chemical fertilizers used, particularly nitrogen fertilizers, are lost to the environment through "denitrification" and "leaching," which is both environmentally hazardous and uneconomical.

Sustainable farming methods must be used for long-term food production and to lessen the fragile effect on the environment. In such a scenario, organic farming has recently attracted positive attention in line with rising environmental consciousness and health concerns. In this context, the use of microbial inoculants as bio-fertilizers is thought to play a vital part in the start of a "microgreen revolution." Crop plant development and yield are impacted by the existence of an active population of soil microorganisms in the rhizosphere, including bacteria, algae, fungus, and protozoa. Hiltner first introduced the idea of a "active layer of soil microbes in the area surrounding plant roots, which are activated by root products" in his original description of the rhizosphere[1].

Due to the activity of the roots, it has a distinct composition from the rest of the soil. The role and intended outcome of plant growth-promoting rhizobacteria have received a lot of attention among the many soil microorganisms found in the rhizosphere. The PGPR are bacterial species that live in the rhizosphere and promote plant and root development via several direct and indirect methods. Bacteria make up the majority of the microbial population in the rhizosphere, with the species Bacillus and Pseudomonas predominating. Some PGBR actively aid in the development of plants by synthesizing and secreting compounds that stimulate growth as well as by providing readily accessible vital nutrients via processes like biological nitrogen fixation and phosphate solubilization. Some PGPRs encourage plant development by preventing harmful effects brought on by plant infections, which result in nutrient loss. The bacteria that cause BNF in the PGPR are known as "diazotrophs," and they transform elemental nitrogen into forms that plants can use. The most researched diazotrophic PGPR is rhizobia. Through symbiosis with actinomycetes and root legumes, they are able to fix atmospheric nitrogen. Forage and grain grasses, on the other hand, are the primary sources of food in the contemporary world for non-legumous plants. The main substitute for the symbiotic relationship between legumes and Rhizobium is Azospirillum.

The Azospirillum genus' taxonomic trait of motility is significant. This helps the bacterial cells travel in the direction of rich nutrition sources. The "single polar flagellum" found in Azospirillum cells allows them to swim, making them extremely motile in liquid conditions. The genus has a flexible nitrogen and carbon metabolism. As carbon sources, the cells use a range of salts of organic acids, including malate, oxalate, succinate, lactate, and pyruvate, as well as certain sugars, including fructose and glucose, and amino acids that are found in the rhizosphere and in microbial sources. Azospirillum amazon-ense is the only species in the Azospirillum genus that can live on sucrose as the sole carbon source, whereas Azospirillum irakense is the only species that can grow on pectin. The bacterial cells get their nitrogen from a variety of sources, including ammonium ions, nitrate ions, nitrite ions, amino acids, and atmospheric nitrogen. The cells of the azospirillum have a few distinctive characteristics[2].

Chemotaxis

Chemotaxis is the mechanism that causes bacteria to recognize and travel to the most advantageous niche, full of nutrition sources. This characteristic aids in the bacterial cells' ability to endure in the rhizosphere's plant-microbe interactions. By controlling gene expression or altering the swimming pattern, signal transduction systems let cells detect and respond to these changes. Azospirillum spp. exhibits this chemotactic activity toward a number of amino acids, mono- and disaccharides, and different organic acids released by plant roots. This characteristic is influenced by both the bacterium's motility and the attractant chemical molecules. It was discovered that the chemotaxis of Azospirillum species is strain-specific. Plants like kellar grass, sugarcane, and sorghum utilize the C4 cycle, also known as the Hatch-Slack pathway, to carry out the dark reaction of photosynthesis, while plants like wheat, rice, cotton, and sunflower use the C3 cycle, also known as the Calvin cycle.

The first group of plants are known as C3 plants, and the second group as C4 plants. In research, it was shown that Azospirillum strains obtained from C3 plants showed considerable affinity to malate but not to oxalate. The main organic acid released by the roots of the C3 plant in this instance is malate. Azospirillum brasilense was shown to preferentially colonize the roots of these plants. However, the strain that was isolated from C4 plants, where oxalate is the main organic acid released, demonstrated intense adhesion to the oxalate. In this instance, Azospirillum lipoferum was shown to preferentially colonize the plant roots. It has been shown that Azospirillum's main chemotaxis route relies on "proton-motive force-sensing." The evidence for this was the obvious correlation between changes in membrane potential, the main component of "proton-motive force," and variations in chemotactic behavior. The host specificity in colonization by the Azospirillum species is directed by the chemotactic pattern in Azospirillum cells.

Aerotaxis is a characteristic that has been particularly shown to be present in the genus Azospirillum, and it allows the bacteria in that species to migrate toward an ideal oxygen concentration. This activity enables the bacterial cells to thrive in both carbon-rich and nitrogen-poor environments, be highly adapted and adaptable, and survive for extended periods of time in competition with other microbes. One of the main motivations for attracting the bacteria to the plant roots is the gradient created by the low oxygen availability in the rhizosphere. This works well in directing the bacteria to locations where they can fix nitrogen from the air.

Cyst and aggregate or floc formation

Azospirillum cells, especially vegetative Azospirillum cells, have the capacity to change into inflated "cyst-like" forms under unfavorable circumstances including withering and nutritional deficiency. These forms are non-motile, very refractile, and accompanied by the formation of granules of the abundantly occurring poly-hydroxybutyrate and an exterior coating of polysaccharides. The polymer is created and kept within the cells by the cells themselves. This development is crucial because the PHB granules serve as carbon and energy sources for growth, proliferation, and nitrogen fixing under adverse starvation circumstances. These are regarded as "real cysts" because of how well they withstand gamma, ultraviolet, and withering radiation. The cyst formation enables Azospirillum cells to thrive under challenging circumstances[3].

Additionally, Azospirillum cells have the capacity to aggregate, forming visible flocs, along with a lack of motility, in the presence of certain unfavorable physiological circumstances, such as high pH levels and high carbon-to-nitrogen ratios, which are detrimental to the bacterial development. In comparison to free cells, the flocs generated exhibit higher drought resilience. These bacterial aggregations are created when cells congregate and establish a multicellular relationship that is stable and nearby. Cellular aggre-gation is caused by natural polymers such polysaccharides and polyaminoacids that are secreted at bacterial cell surfaces. These polymers are of a length that will allow them to act as bridges between the microbial cells. It is taking place a very particular and reversible cellular aggregation. The strong affinity between the adjacent surfaces is what gives rise to these characteristics. In general, there are three kinds of "microbial aggregation" systema stage before differentiation and morphogenesis.a stage before sexual and parasexual behavior. A means of surviving in various situations.

The third group includes the aggregates produced by Azospirillum as well as other nitrogen-fixing free-living bacteria including Azotobacter and Klesbiella. The Azospirillum aggregates are known to be trapped under the fibrillar material connected to the plant roots. Depending on the situation, Van der Waals interactions, hydrophobic contacts, ionic interactions, or hydrogen bonds may be the main interactions driving cell-to-cell adhesion. Using culture media that are rich in carbon sources, such as fructose, gluconate, malic acid, and PHB, may help to speed up the process even further. Only the sugar arabinose has the power to completely prevent the aggregation of Azospirillum brasilense cells[4].

Rhizosphere and Bulk Soil Survival

Azospirillum species make up over 10% of the entire microbial population in the rhizosphere, whereas they only make up 0.2% of the population in bulk soil and tropical soil. According to a research, there are 300 times more Azospirillum brasilense occurrences in the rhizosphere. The ability of the soil to retain water influences how long bacteria can survive in bulk soil. The top soil surface often irreversibly absorbs the azospirillum cells via a charge-charge interaction. The soil's surface area and the charge of the surface particles are directly related to the degree of adsorption. Clay and organic matter are crucial soil constituents. These significantly influence how much adsorption occurs. Given that all clays and organic materials have net negative surface charges and hence are unable to make contact with one another, it is crucial to understand how charge-charge interaction occurs between the bacterial cell and these surfaces. This may be explained by the fact that the clay surface has positively charged edges to which the bacteria adhere. Under comparison to aerobic settings, it was discovered that the adsorption was greater under microaerophilic conditions. By introducing bacteria attractants, it was possible to compare the capacity of adsorption and motility of the Azospirillum cells. It was found that the motility generated by the attractants' ability to pull the bacteria was greater than the ability of the bacteria to adsorb to the soil. Azospirillum cells were shown to have limited adsorption to sandy soils.

According to a research, quartz sand was poorly adhered to the surfaces of light- and heavy-textured soils by Azospirillum brasilense Cd cells.According to a research, "partial failure" in root colonization after Azospirillum spp. inoculation may occur when the bacteria is firmly adherent to the soil surface, resulting in inadequate cell availability prior to colonization. The cation exchange capacity and redox potential of the soil are the other two soil factors that affect the amount of adsorption. It was shown that when CEC increases, the total percentage of adsorbed cells also rises, but soil redox potential, which impacts the degree of adsorption, directly affects the bacteria's capacity to fix nitrogen. It was discovered that the bacterial cells were not evenly dispersed throughout the soil surface. Their relative mobility via the capillaries or pore spaces has a significant impact on how they are distributed.

Azospirillum brasilense Cd, which was uniformly scattered throughout the soil, was the rare exception. Another significant finding is that living bacteria exhibit greater levels of adsorption than dead bacteria. Agitation, the use of ethylenediaminetetraacetic acid, protease, bacterial inhibitors, and high temperature exposure are some of the factors having a negative impact on bacterial adsorption. Azospirillum strains cannot develop at too low a temperature either. After the removal of the plants growing in the soil containing the bacterium, Azospirillum brasilense's ability to survive was greatly reduced. This is due to a decline in the nutritional supplies that plants formerly offered for the development and survival of bacteria. It has been shown in India that adding rice straw to flooded soils increases the number and length of time that Azospirillum bacteria survive[5].

Antagonism with other microorganisms that dwell in the rhizosphere is another crucial feature that has a significant impact on the survival of the genus Azospirillum there. Azospirillum spp. populations were found to be much lower in temperate and cold niches than those of other rhi-zosphere microorganisms. The bacteria "infect" and "proliferate" within the plant root tissue in the case of nodule-forming Rhizobia, avoiding competition with other rhizosphere germs for resources. But in the case of free-living Azospirilla, the bacteria must contend with other soil microorganisms for nutritional sources. In addition to the competition for food sources, there is also a competition for survival since the development of certain microorganisms has a significant impact on the development of others. This is explained by the fact that particular strains of the bacteria Azospirillum lipoferum and Azospirillum brasilense produce a specific family of chemicals known as bacteriocins, which hinder the development of closely related bacteria in vitro. It has been shown that Bdellovibrio sp. parasitizes the bacteria of the genus Azospirillum in soil, where they provide food for soil protozoa. Once again, the growth of B. japonicum was increased by the Azospirillum lipoferum strain while having no effect whatsoever on the growth of the Azospirillum lipoferum strains.

Azospirillum and Induction of Stimulatory Effects for Promoting Plant Growth

Inoculation with Azospirillum spp. induces various stimulatory effects in the inoculated plant. It includes healthy growth of leaves, increased dry matter, elongation in root, and improved yield. Increased mineral and water uptake was also observed in Azospirillum inoculated plants. The beneficial effects exerted by the organism were initially believed to be induced by its ability of atmospheric nitrogen fixation. But, it was later established that the contribution of the nitrogen content affixed by Azospirillum spp. is very less, as the plants do not take up major portion of the nitrogen converted by the organism. As a matter of fact, it was the production and secretion of some beneficial organic substances by Azospirillum spp. that actually uplift the overall plant growth. Various effects, combined with specific mechanisms, lead the route to growth promotion. The mechanisms used by Azospirillum spp. in promoting plant growth are discussed below.

Nitrogen Fixation

It is the principal mechanism followed by Azospirillum, leading to growth induction. Though it has actually very less contribution in plant growth promotion, it still holds crucial importance in supplying the plants with essential nitrogen content. Acetylene reduction assay displayed the assimilation of atmospheric nitrogen into host plants. Azospirillum spp. converts atmospheric nitrogen, which cannot be used up by the plants directly into the plant usable ammonia form in micoaerobic conditions. The enzyme responsible for this action of Azospirillum spp. is nitrogenase

DISCUSSION

Azospirillum spp. are the most studied free-living nitrogen fixing plant-growth promoting rhizobacteria. The versatile beneficial effects exerted by the genus make it interesting and draws attention, in order to thrive deeper for better understanding of its properties and mechanisms of various actions, for enhanced future applications. The associative-symbiosis in the grass-bacteria systems can be distinguished from the legume symbiosis by various techniques, including immunofluorescent technique, fluorescent antibody technique, and serological tests. It was possible to identify the individual cells by these techniques. Strains of Azospirillum brasilense were isolated from Ecuador, Florida, and Venezuela and established their nitrogen fixing ability. Then, by employing fluorescent antibody technique, the individual strains were

Azospirillum for Sustainable Agriculture

Identified Bashan et al. carried out different investigations to comprehend poor survivability of Azospirillum spp. in 23 different types of soils using two strains of Azospirillum brasilense: Cd and Sp-245. In tropical seasons, the strains of Azospirillum inoculated were found to have not survived from one season to the next. In Israeli soils, it was observed that the Azospirillum cells strongly adhered to the clay and organic matter in topsoil hardly eroded downward. The formation of cysts, fibrillary materials, made the bacteria stand out among other rhizobacteria, which on experiment, were easily washed down when percolated. Bashan et al. Found that enormous numbers of viable bacterial cells were observed in the vicinity of the root surface, regardless of the soil characteristics. But, as soon as the plants were drawn apart from the soil, the survival of the bacterial cells diminished.

To use Azospirillum inoculants as commercial Bio-fertilizers in large-scale demands sufficient bacterial bio-mass. Fallik et al. Innovated technique for the production of Azospirillum biomass in a "fed-batch fermentor". In their work, they used succinic acid as the source of carbon and liquid ammonia as the nitrogen source. It was observed that within 24 hours, the viable cell number became 1–3 × 1010 cfu/ml. As for the carrier of the Azospirillum species, ground or granular peat was recorded with highest number of viable cells, compared to talcum powder, bentonite, vermiculite, etc. Faure et al. Studied the activity of Azospirillum lipoferum laccase on phenolic derivatives. The lac-cases are the phenol oxidases, common in fungi and higher plants. This had been associated only with Azospirillum lipoferum, isolated from rice roots. The laccase components convert the ortho- and paradiphenols, to ortho-and paraquinones, respectively. The result obtained displayed the conversion of phenolic compounds of aldehydic, acidic origin, or acetophenone type, were converted into 2, 6-dimethyl-1, 4-benzoquinone, by the activity of Azospirillum lipoferum laccase. Various works were carried out to demonstrate the capacity of Azospirillum spp. in increased growth of microalgae in freshwater surface. The strain of Azospirillum brasilense for enhanced growth of Chlorella vulgaris, a fresh-water microalgae, essential in tertiary wastewater treatment.

Their work reported inoculation of Chlorella sp. with a PGPR for the very first time. Alginate beads were used to immobilize the two co-inoculated species, ensuring close contiguity between them. The result obtained was quite satisfactory. The desired growth of the microalgae was observed, accompanied with significant increase in cell number, level of pigments, dry and fresh weight after inoculation with the Azospirillum species. The property of aggregation or flocculation of the genus Azospirillum had always attracted close attention of the researchers, comprising the facility to offer the cells better survival capacity. The composition of exopolysaccharide and capsular polysaccharide of four Azospirillum brasilense strains having difference in aggregation ability. The cell aggregation property was analyzed by high performance anion exchange chromatography. They reported coinciding relationship between rate of aggregation and amount of arabinose present. A study to contextualize the biochemical activities of Azospirillum brasilense and Azospirillum lipoferum under controlled culture conditions. In both the species, production of EPS and CPS in large amounts was observed. After extinction of carbon sources from the cul-ture, the polysaccharides were shown to be consumed. This implied that they were, in fact, used as carbon sources by the bacteria.

The uptake of oxygen was found to be high during fructose assimilation and low during polysaccharide degradation. Herschkovitz et al. Utilized "molecular phylogenetic probes" and primers on 16S rRNA and rDNA of Azospirillum brasilense to investigate its impact on rhizosphere colonization and the composition of microbial community in two soil systems. It was observed that the species on inoculation did not affect the composition of the micro-bial community. The adhesion of the bacterial cells on solid substrates is related to the outer membrane of the microbial cells. The biofilm forma-tion, resulting from bacterial colonization on solid surfaces in marine environments, leads to material degradation. To correlate these facts and to comprehend the control of this biofilm formation in sea water, Pradier et al. Carried out a study on the chemical composition of the bacterial surfaces in some marine bacterial strains. The D41 strain tested exhibited the presence of proteins. This strain gets attached to surfaces of stainless steel, glass, Teflon, etc. more in comparison to the strains DA and D01. The role of the protein present was demonstrated to have influence over the adhesion to a greater extent than the hydrophobicity.

As the Azospirillum-plant association leads to enhanced water uptake by the plant roots, inocu-lation with Azospirillum spp. is expected to reduce the water stress condition, thus promoting healthy plant growth. Pereyra et al. Performed an investigation, establishing the positive effects of Azospirillum spp. on plant water-stress condition. They inoculated Triticum aestivum seedlings with Azospirillum brasilense Sp-245, under supervised conditions of darkness and osmotic stress and tested for changes in composition of phospholipids and distribution of fatty acids. It was observed that inoculation with Azospirillum spp. prevented leakage of ions and enhanced 2, 3, 5-tripheniltetrazolium reducing capacity in the roots. The tolerance to water stress was found to be mediated by changes in the profile of fatty acid distribution of principal root phospholipids, phosphatidylcholine, and phosphatidylethanolamine. Another important factor arising from the plant root association with Azospirillum is the production of phytohormone, which assist the growth promotion, alongside nitrogen fixation. Perrig et al. Carried out systematic investigation of phytohormone and polyamine production in the two Azospirillum strains: Azospirillum brasilense Az39 and Cd. The study also led to discovery of siderophore production and phosphate solubilization by these two strains. In controlled medium, the strains synthesized five major phytohormones, along with important growth regulator, cadaverine.

The production of one of the most important growth regulator, IAA, was demonstrated by the work of Crozier and his co-workers. They isolated some strains of Azospirillum brasi-lense and Azospirillum lipoferum from maize and teosinte roots proceeded for quantitative analysis of the synthesized IAA and similar indoles.

It was reported that in the culture medium of Azospirillum brasilense 703Ebc strain, growth regulators such as IAA, indole-3-ethanol, and indole-3-meth-anol indole-3-lactic acid were present. However, the main source from where the IAA was originated, whether it was bacteria or the plant was not clarified. Due to the enormous plant growth promoting effect of Azospirillum spp., it has been marketed as commercial inoculants for agricultural applications. Most of the marketed inoculants are formulated as peat-based for seed coating or as pellets for sowing. However, in some cases, polymer coatings as carriers have been used in the formulations for better survival and activity of the inoculants in challenging environmental conditions.

The polymer coatings help the inoculants in survival as well as optimize the application by controlled release from the coatings for a pro-longed period. Bashan et al. Encapsulated two plant growth promoting rhizobacteria, Azospirillum brasilense Cd and Pseudomonas fluorescence 313 in two different alginate beads and stored for 14 years after drying. Though the initial population declined in both the beads, yet a significant number of cells survived, thereby demonstrating the ability of the polymer coating to protect the inoculants for a very prolonged period. Various applications of commercial Azospirillum inoculants were carried out in agricultural field, monitoring the growth of several crops. Piccinin and his collaborators inoculated wheat seedlings with Azospirillum brasilense strain and investigated the overall growth and the agronomic yield. Positive results were obtained with enhanced growth and raised annual production[6].

Challenges in Large-Scale Commercial Applications of Azospirillum Inoculants

The versatility of the Azospirillum genus in exhibiting critical plant-growth promoting properties, either by nitrogen fixation or by secretion of essential compounds for growth stimulation is highly beneficial for plant growth. Certain substances produced and secreted by these organisms play important role in hazardous compound accumulation in the rhizosphere. Being the free-living non-legumous diazotroph, Azospirillum spp. turns out to be the satisfactory substitute for legumous Rhizobia, with the additional advantage of not having to be too precautious for the handling of the inoculant for field applications. For such numerous crucial advantages and usability of these organisms, they are being utilized in the agricultural field in large-scale commercially, enhancing the overall growth and yield.

Biofertilizers:

Of crop plants and environmental protection. But there exist certain constraints, which make the large-scale commercial applications of these inoculants troublesome. They are discussed below.

Resource constraints:

There exist problems including lack of suitable strain for inoculation, unavailability of quality supplies, and inaccessibility in proper infrastructure, added with the unaware-ness of the manufacturers for the value of products.

Production constrains:

The lack of knowledge, research on the quality of the inoculants as commercial products restraints the manufacturers to attain the products with superior quality.

Market constraints:

The ignorance of the manufacturers toward the marketing of the products, followed by the restraining the financial aspects.

Field constraints:

The practical implications of the inoculants on field are very different from the theoretical perspective in reality. This arises because of diverse environmental conditions, along with a huge population of indigenous rhizosphere microorganisms, which might adversely affect the growth and activity of the Azospirillum cells.

Technical Constraints:

Technical constraints can be crucial, when the source strain turns out to be unauthentic. Other technical problems may arise due to mishandling, inappropriate adoption of certain techniques, leading to contamination, destruction of the source strain and poor yield. Programs Employed for Enhanced Applications of Azospirillum Inoculants. Governments of many countries around the world have displayed close attention in practicing sustainable organic agricultural technologies, in correspondence to the global hiking of environmental pollutions, coming from utilization of conventional inorganic fertilizers. Many policies and funds have been introduced by the governments across countries in order to promote sustainable agricultural practices. “Common Agricultural Policy” has been promoted by the European countries granting 30% of the funds to the farmers as a “green payment”. The Taiwan government has introduced a policy to promote the use of bio inoculants for nitrogen fixation, phosphate Solubilization, etc. They have engraved peer pressure in utilizing these bio products for soybean cultivation, which is traditionally consumed in the country as vegetable, peanut, and red bean, ensuring sustainability.

The Indonesian Agricultural Sector also took up certain programs to improve the declined yield of crops by using bio products. The Indian Government also introduced certain policies to promote the bio product usage in agriculture throughout the country and also to enhance the market value for the bio products, to support the small-manufacturers. Policies such as "National Mission of Sustainable Development /Paramparagat Krishi Vikas Yojana", "Rashtriya Krishi Vikas Yojana", and "National Mission on Oilseeds and Oil Palm" have been introduced for the sustainable agricultural purpose. The Indian Council of Agricultural Sciences started the "National Organic Program ", which was previously executed by the US Department of Agriculture for improvement in the quality of the agricultural yield, obtained through organic manner [7], [8].

CONCLUSION

In the context of increasing global awareness about environmental pollutions and worldwide "green" safety protocols, application of bio inoculants in agricultural field is accepted to be a much anticipated mode for sustainable agricultural development. The stimulatory effects of Azospirillum spp. as discussed are displaying its versatile applications ensuring environmental safety.

However, for large-scale applications as commercial inoculants, there emerges certain complications regarding their production, long time survival, marketing, etc. Further studies on the genomic structure of Azospirillum spp. can lead to better understanding of the metabolic route taken by the organism and, hence, can create scope for innovated enhanced application in various fields.

There is certain necessity in expanding the awareness about the bio inoculants worldwide, regarding their proper handling, proper technical application, and sophisticated storage methods. The agricultural societies and government across the countries should adopt further policies and awareness programs regarding the issue and grant more funds in this field to inspire further improvement and innovations of bio products.

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CHAPTER 11

IMPLICATIONS AND PROSPECTS FOR ACTINOMYCETES IN SUSTAINABLE AGRICULTURE

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ABSTRACT:

Biofertilizers are regarded as one of nature's greatest gifts to humans. The dormant microorganisms, which are the Biofertilizers' active components, have assisted to address environmental and health problems brought on by the indiscriminate use of harsh chemical fertilizers. In an integrated nutrition management system for sustainable agriculture, Biofertilizers play a significant role. The importance of actiomycetes among the many kinds of microorganisms in nature cannot be overstated. They are very significant in the world of agriculture due to their vast population in a variety of soil types and their dynamic character to maintain soil fertility and ecology. The agricultural industry benefits immensely from actinomycetes' biological management of the soil environment. These organisms have a variety of traits that include the capacity to promote plant development, control plant health and vigor, and the production of agroactive chemicals. Actinomycetes play an important part in the resilience of ecosystems because of their ability to reduce the harmful and dangerous impacts of chemical fertilizers while simultaneously promoting beneficial effects in plants. Future crop output will greatly benefit from these filamentous bacteria' enormously favorable impacts on the soil.

KEYWORDS:

Actinomycetes, Agro Active Compounds, Biofertilizer, Sustainable Agriculture.

INTRODUCTION

Bio-fertilizers are regarded as a crucial component of this management system for nutrient management, which deals with the conservation of soil by managing vital soil nutrients at their optimal and optimum levels. Biofertilizers are thought to offer an advantage over chemical fertilizers. They stand out because they are both safe and environmentally friendly while still being quite effective. Biofertilizers are compounds that include effective, live microorganisms that help improve and support plant production by better extending necessary nutrients to the host plant. Their contribution to environmentally friendly, efficient crop production is of utmost significance in the agriculture sector. These characteristics of Biofertilizers are inspired by the bacteria that make up their base. Most of the beneficial qualities that a Biofertilizer should have are often provided by the bacteria.

As tools for ensuring the safety of food and promoting sustainable agricultural practices, Biofertilizers have impressive properties that include nutrient mobilization and mineralization, acting as efficient biocontrol agents against various plant diseases, supporting plants under biotic and abiotic stress, and preserving soil ecology and fertility by adding various plant growth-promoting elements, among others[1]. All these characteristics are a result of the microorganisms found in Biofertilizers. The manufacture of Biofertilizers is thought to be suitable for a wide variety of microorganisms. However, actinomycetes stand out among them. Actinomycetes differ significantly from bacteria and fungus in that they play a crucial part in the soil ecosystem and provide advantages to both industry and agriculture. Actinomycetes are potential candidates for producing Biofertilizers because they have the distinctive ability to release a variety of secondary metabolic derivatives and substances that have antibacterial, antifungal, and antagonistic properties.

When it comes to the generation of bioactive chemicals among the enormous, varied microbial population, actinomycetes rule the roost. Actinomycetes create roughly 50% of the 23,000 different types of bioactive chemicals that are produced by microorganisms, according to reports. Some of these include weedicides, insecticides, and growth-regulating substances as well as antibacterial, antivirals, and agro biologicals. Their capacity to thrive in a variety of soil environments allows them to participate in a number of soil processes, including phosphate Solubilization, humus production, and nitrogen fixation, to mention a few. Actinomycetes are perhaps the most spectacular and powerful rivals for Biofertilizer formulations due to their synthesis of agroactive chemicals and subsequently their significance in sustainable agriculture.

Actinomycetes are one of the most extensively dispersed organisms in the great variety of bacteria that live on Earth and among nature. The natural inhabitants of soil are actinomycetes, which span about 100 genera. With high amounts of G+C content, actinomycetes, which are members of the order Actinomycetetales, may be recognized from other microorganisms. These gram-positive bacteria live in the soil as saprophytes. They can break down complex carbohydrates like starch and chitin and other forms of organic debris like lignocellulose since they are saprophytic soil dwellers. They exhibit morphological mycelia development that leads to sporulation. Actinomycetes are often found in extremely high concentrations in semi-arid soil environments, while they have also been found in very low levels in other climatic settings. Actinomycetes often require low levels of moisture for development and survival and are particularly well adapted to semi-dry settings. This is likely because they can produce spores even in dry environments. Actinomycetes are often mesophilic, while certain species may also be found in settings that are thermophilic. They have a broad variety of hosts and may even develop as epiphytes[2].

Actinomycetes have recently attracted a lot of attention from microbiologists due to their variety of features, which make them an excellent source for the creation of bio inoculants. Actinomycetes are important bacteria that may increase the general health and productivity of agricultural plants. They may either be sprayed on crop seeds or added directly to the soil. Actinomycetes have been shown to have a direct impact on plant development via processes such as nitrogen fixation, phosphate Solubilization, the creation of growth hormones, or indirectly through the scavenging of iron through the formation of siderophores, which protects plants against diseases. Additionally, by intensifying their suffering from different stress circumstances, they have an impact on their development.

Streptomyces is a well-known genus of actinomycetes. Over 75% of the many known active biological chemicals come from the Streptomyces and other actinomycetes species. Actinomycetes have attracted a lot of interest for a long time because of their ability to produce antifungal compounds that may suppress a wide variety of fungal infections, defending plants against a wide range of fungal illnesses. Antibiotics and extracellular enzymes may be found in abundance in actinomycetes. Not to mention, their potential value as a source of biocontrol components, biologically active agricultural agents, and plant growth-promoting substances.

Function in Preserving Soil Fertility

Fixation of Nitrogen

Nitrogen is a crucial ingredient that restricts plant development. It is essential and unavoidable for plants to have access to and absorb enough nitrogen for them to develop and mature. Because it is used in the creation of significant nitrogenous substances such nucleic acids, amino acids, and proteins, nitrogen is significant for plants. In addition to being required for the production of ATP and nucleic acids, it is a crucial component of the photosynthetic pigment chlorophyll. Despite its abundance in the earth's atmosphere, nitrogen is inert and so unavailable to plants until it is changed into a more palatable form. There are many different microorganisms, including actinomycetes, which have the ability to fix atmospheric nitrogen in both leguminous and non-leguminous plants. However, actinomycetes differ from other nitrogen-fixing microbes in that they have the ability to work more cooperatively with a variety of plants. Because of their capacity to fix nitrogen, actinomycetes are among the best candidates for producing Biofertilizer.

Actinomycetes have the capacity to fix nitrogen and may produce nodule clusters. While some actinomycetes benefit the plant by coexisting in the soil independently, others interact with the plant to permit their capacity for nitrogen fixation. The positive impact on plants is clear in any scenario. Numerous research have been conducted on the group of actinomycetes that interact with plants in one way or another, improve soil fertility, and hence influence the kind of plant development. Actinomycete species with particularly strong plant-microbe interactions are crucial to the health of the plant. According to Tokala et al., the root-colonizing actinobacterium Streptomyces lydicus WYEC108 interacts in a special and very potent way with the leguminous plant Pisum sativum. The root-colonizing soil actinomycetes, Streptomyces, make this relationship between the actinomycetes and the pea seem to be of the highest significance.

Agriculture Sustainability and Actinomycetes

Lydicus WYEC108 impacts the pea root by significantly increasing the frequency of root nodulation in addition to encouraging the establishment of healthy nodules in legumes. As a leguminous plant, the pea is also known to form symbiotic relationships with microorganisms. According to studies, Streptomyces lydicus most likely colonizes the pea root at the same time as the common symbiotic Rhizobium species infects the pea plant to produce root nodules. After colonization, these active bacteria begin to sporulate within the nodules and specifically inside their cell layers. Therefore, such colonization by both Rhizobium and Streptomyces may lead to an increase in nodule size, which ultimately aids in enhancing the vigor of organisms inside the root nodules. This facilitates the nodules' better absorption of a variety of vital soil nutrients. Therefore, it may be obvious that a number of significant actinomycetes, such as Streoptomyces, work as organic soil fertility enhancers to increase the development of many other leguminous plants in addition to peas. Such research results provide strong evidence that many actinomycetes can fix nitrogen and may function alone to support plant development and health, but it is also important to note that they are very compatible with other root nodulating organisms[3].

Additionally, it is thought that certain actinomycetes, when coupled with other nitrogen-fixing bacteria or microorganisms, exhibit exceptional improvements in nitrogen fixation while having low to mediocre N2 fixation capabilities as standalone organisms. Soe et al. conducted experiments to support their findings. Bradyrhizobium japonicum strain USDA 110 and Streptomyces griseoflavus P4 strain that was isolated from pea root nodules were successfully tested for compatibility. According to reports, the combination significantly affected the dry weight of nodules, the accumulation of nitrogen in the shoots, the weight of the seeds, etc. Streptomyces griseoflavus P4 and Bradyrhizobium japonicum alone did not increase nodulation or seed weight, but their combination had a considerable positive impact on soybean. Some of them included better nitrogen fixing and improved nodulation.

DISCUSSION

There have been reports of nitrogen-fixing properties in Frankia ceanothi. This actinomycete is an endophyte that lives within the Ceanothus greggii shrub's cortex. Long believed to be exclusive to the genus Frankia, actinomycetes other than Frankia have been shown to carry nif genes and catalyze atmospheric nitrogen into a more assimilable form. Nif genes have been found in non-Frankia actinomycetes such Slackia exigua, Rothia mucilaginosa, and Gordonobacter pamelaecae, according to Gtari et al. Their ability to thrive and reproduce in a nitrogen-deficient environment as well as their capacity to decrease acetylene served as proof. These nif gene sequences are reportedly passed on either vertically or horizontally. Numerous actinomycetes other than Frankia have been shown to be capable of fixing nitrogen. In the early stages of their life cycles, all actinomycetes, including Frankia, exhibit characteristic filamentous cellular shape. These filaments eventually get fragmented. In addition to having the capacity to fix nitrogen, the actinomycetes species Streptomyces, Actinoplanes sp., and Micromonospora sp. According to reports, these substances have an encouraging influence on shoot development and improved actinorhizal symbiosis with Frankia. Additionally, it has been shown that these atinomycetes create bioactive compounds.

Solubilization of Phosphate

The availability of all important nutrients, including phosphorus, is necessary for plant development. It is the foundation for the synthesis of numerous macromolecules, respiratory chain components, energy transduction activities, etc., which makes it vital to plants. Phosphorus can only be absorbed by plants in soluble form, which is bad since soil insoluble forms are inaccessible to plants. Transforming from soluble

Agriculture Sustainability and Actinomycetes

The presence of significant amounts of cations facilitates conversion to insoluble form. In addition to reducing soil fertility, the issue of phosphorus precipitation has also cost farmers much more money due to lower agricultural output. These problems have prompted researchers to hunt for potential remedies, which has led to the use of phosphate-solubilizing microorganisms in crop cultivation. A variety of soil-dwelling microorganisms, such as bacteria, actinomycetes, fungus, etc., fall within the category of microbes that solubilize phosphate. These organisms are thought to produce specialized enzymes that solubilize phosphorus and make it accessible to plants.

Actinomycetes likely have an advantage over other phosphorus-solubilizing microbes because they are more numerous in the rhizosphere soil than other microbes and because their slower but more consistent degradative processes than bacteria or fungi enable them to continuously release soluble phosphorus throughout the plant life. One such group of organisms, the actinomycetes, aids in enhancing plant growth and, therefore, agricultural yield. The nutritional value of the soil and the ability of plants to absorb and digest such plant supplements ultimately determine plant development and the agricultural production from such plants. These creatures' ability to live on the plant root exudates, which is their sole source of nutrition supply, is a significant and admirable characteristic[4], [5].

These actinomycetes assist in the release of soluble phosphate in exchange. Streptomyces is the most significant group of actinomycetes having the capacity to solubilize phosphate, although other actinomycetes besides Streptomyces include Micromonospora endolithica, Gordonia, Rhodococcus, and Arthrobacter.

Actinomycetes have developed to use several strategies to convert insoluble phosphates into soluble form. By secreting the enzyme phytases, certain actinobacteria solubilize insoluble phosphates. These extracellular enzymes, which are a part of the phosphomonoesterase group, allow for the gradual breakdown of phytate. Actinomycetes may also assist phosphate solubilization by generating a mixture of acids including oxalic, malic, propionic, and gluconic acids, which together create an acidic environment. Insoluble phosphates are converted into usable form and made accessible to plants by the acidic pH of the soil close to the rhizosphere.

The phosphate-solubilizing actinomycetes, like Streptomyces griseus BH, perform many tasks, such as inhibiting possible phytopathogens including fungi, yeasts, and bacteria. They also operate as soluble phosphate providers for the plants. When compared to controls, certain strains of Streptomyces have been observed to generate a staggering rise in wheat aerial growth and biomass of more than 30% under farm settings and almost 70% in in vitro tests. Such studies are thus very persuasive for the development of actinomycete-derived Biofertilizers and biocontrol agents.

Solubilization of Potassium

Potassium is another crucial element needed for plant development. For stomata holes to open and close, plants typically absorb potassium in its ionic form. By blocking the harmful effects of reactive and unstable oxygen species, potassium is also linked to the detoxification process in plants, which reduces the impact of stress on them. Additionally, its function in several metabolic and respiratory chain activities is well documented. Potassium deficiency is known to render plants susceptible to a variety of plant diseases, including insect infestation. Due to the current crop production system's rigorous methods and the adoption of high-yielding cultivars, potassium levels are often depleted along with other crucial plant macronutrients. Utilizing potassium-solubilizing microorganisms to replenish reduced potassium levels and restore soil fertility is an environmentally acceptable method of integrated nutrient management. These microorganisms do this by a number of methods, including chelation, the exchange and complexation reaction, and the formation of organic acids followed by acidolysis. Numerous Streptomyces species, including Streptomyces sp., have been found to have strong potassium solubilizing activity. Streptomyces species and KNC-2. TNC-1.

Maintaining Soil Ecology's Role

Actinomycetes are known to be widely distributed at the plant's root-soil interface. It is well recognized that these bacteria have beneficial impacts on plants. On the same vein, applying Biofertilizers made from actinomycetes may still boost the abundance. The strategy of incorporating actinomycetes in the form of Biofertilizers would benefit crop plants and increase crop yields as required by the current state of agriculture, which uses chemicals as fertilizers indiscriminately, leading to a decline in soil fertility and its nutritional value. Actinomycetes are recognized to have certain chemicals that improve plant development potential and support soil ecology. Cellulase, amylase, protease, phytase, chitinase, and phosphatases are just a few of the extracellular enzymes that these organisms have the special ability to produce in soil.

Agriculture Sustainability and Actinomycetes

By recycling the nutrients, these exoenzymes support soil's ecological health. In the plant rhizosphere soil, these enzymes aid organisms in using the nutrients released by the plants. As a result, both soil ecology and fertility are improved. This activity contributes to the creation of a nutrient pool of sugars, amino acids, peptides, organic phosphorus, and many other crucial supplements in the rhizosphere. Actinomycetes have the potential to promote plant growth, ensuring that plants expand extensively and develop in terms of their root length, plant height, vigor, and overall better biomass.

Actinomycetes, which include many different species, are known to play an important function in the rhizosphere by reducing harmful species while simultaneously promoting the establishment and reproduction of beneficial groups of soil microbes including nitrogen-fixing bacteria. For instance, Azotobacter sp. colonization was boosted when Streptomyces fumanus was sprayed or treated to wheat seeds in the form of Biofertilizer. Assisting with additional nitrogen additions to the soil. Additionally, actinomycetes have shown the ability to maintain a balance among the rhizosphere's occupants and to encourage the release of substances that promote development from these residents. This has been found to support and enhance soil ecology, which in turn leads to increased plant growth. By creating growth-stimulating substances like auxins and cytokinins, a healthy soil ecosystem makes sure to offer all the necessary services for overall plant growth and development, resulting to an increase in the number of lateral root hairs. This aids in the growth of a suitable and good surface root system.

Actinomycetes are creatures that resemble filamentous threads. Their strong hyphal networks enable them to break down lignocellulosic organic compounds like lignin and xylan, breaking down complicated polymers into more easily digestible forms. Actinomycetes' capacity to degrade materials is essential for creating compost from plant debris that is healthy for plants. Actinomycete representatives, mostly Streptomyces such as S. Griuse, S. wordoviolaceus, S. Globulus, S. A. albovinaceus S. vesicaria S. setting, S. Virgina, S. S., and R. The hydrolytic extracellular enzymes chitinases, cellulases, glucanases, and peroxidases that are secreted by viridosporus are known to help break down and degrade polymers during composting. This disintegration of polymers into smaller molecules promotes the metabolism of nutrients like carbon and nitrogen[6].

Biocontrol Agents' Function

The traditional pest control methods are now in a serious crisis. Chemical insecticides and pesticides have seriously harmed the environment, but they have also had a negative impact on human health due to the development of resistant pathovars, their comeback, and their capacity to bio accumulate. Additionally, the refractory nature of these compounds is seriously harming biodiversity. These and other problems have compelled scientists to consider alternatives to pest control methods, leading to the development of integrated pest management systems. This approach is based on the idea of biological control, which use living things to either entirely suppress or limit the population density of other living things. Some of the admirable and amazing characteristics of biocontrol agents include protection for crops throughout the crop time, environmental safety, non-toxicity to plants, and, above all, promoting beneficial soil residents. Actinomycetes produce a variety of chemical compounds, including peptides, polyketides, and -lactums, in addition to a large number of secondary metabolic products. According to studies, actinomycetes are the source of around 70% of biologically active substances. We must think of actinomycetes as effective biological control agents because of their many biological roles in keeping plants in good health.

The manufacture of antibiotics

Actinomycetes are thought to secrete a range of bioactive substances in rhizosphere soil of plants, which is thought to have a noticeable favorable impact on agricultural output. Actinomycetes' enhanced defense mechanisms and crop productivity are made possible by their mechanism of antibiosis, which is made possible by the production of several different classes of antibiotics, including erythromycin, oleandromycin, and streptomycin of the macrolides group, kanamycin, and levorin of the polyene group, and erythromycin and oleandromycin of the aminoglycosides group. Streptomyces, Microtetraspora, and Actinoplanes are a few of the actino-mycetes taxa that produce antibiotics.

According to studies, Biofertilizers based on certain actinomycetes, such as Streptomyces fumanus, may effectively promote plant development in a variety of soil types and host cultivars. Actinomycetes-pretreated seeds were shown to accelerate growth and boost yield even in low-fertility and low-irrigated soil. Actinomycete species are excellent manufacturers of antibiotics. These antibiotics have several toxicological characteristics that make them effective against plant pathogens. These microorganisms' capacity to control certain plant diseases may be used. Depending on the plant disease, several types of actinomycetes are utilized for this biological management. At this point, it should be clear that some actinomycetes may be used in leguminous plants as a root-nodulating agent as well as a biocontrol agent.

When the seeds are treated at the time of planting or coated before sowing, the actinomycetes have been observed to display these characteristics. For instance, when Streptomyces species that generate antibiotics were put around alfalfa seeds at the time of planting, it was discovered that the alfalfa seedlings that received Streptomyces additions had formed hyphal filaments and spore chains as opposed to the control with no Streptomyces amendments. These Streptomyces strains also improved the plant's capacity to fix nitrogen by increasing root nodulation. Additionally, the same Streptomyces species, which is capable of manufacturing antibiotics, has the ability to prevent Phoma medicaginis, the bacterium that causes the spring black stem and leaf spot disease in alfalfa, from growing.

It is well known that many actinomycetes, particularly Streptomyces, have an intimate connection with plants and colonize their interior tissues. Streptomyces strains, which are endophytes in tomato roots, have been shown to generate antibacterial and antifungal substances, and they are what prevent Rhizoctonia solani, a fungus that damages the crop and yield, from growing. Additionally, additional actinobacterial varieties, such as Microbispora sp. as well as Streptosporangium sp. are well recognized for their close ties to maize roots and their antagonistic effects on a variety of gram-positive bacterial and fungal diseases[7].

Another plant that supports Streptomyces sp. is Alnus glutinosa. This endophyte is said to create a new antibiotic termed naphthoquinone in its root nodules that defends the host plant against several bacterial and fungal diseases, indicating that the antibiotic has a wide range of activity. Streptomyces strains have a close interaction with plants like tomato and wheat, indicating that the primary reason to house them as endophytes in their tissues is to profit from the secondary metabolites that the endophytes create. These endophytes also possess an ecological advantage over the rival fungal diseases. These reports make it abundantly clear that many actinomycete strains play important roles in plant growth and confer increased resistance to diseases, suggesting that these organisms may have a bright future as potential biocontrol agents for a variety of cash crops like wheat and maize.

It's intriguing to learn that Streptoverticillium albireticuli may have nematicidal activity as part of their capacity to defend plants from different diseases. Numerous Streptomyces species have been isolated and shown to be capable of producing strong antihelminthic compounds, which protect plants against assault by a variety of worms. For instance, it has been discovered that Streptomyces avermitis produces aver-mectins, which are effective against nematodic infections such Meloidogyne incognita and Caenorhabditis elegans. The macrocyclic lactones known as avermectins are a novel family of compounds.

Actinomycetes also have another characteristic that makes it a distinct candidate as an element in biofertilizers. They produce siderophores, which are tiny, iron-chelating molecules with a low molecular weight. Streptomyces is a significant genus of actinomycetes that produce siderophores. For instance, Steptomyces coelicolor is known to generate coelichelin, a peptide siderophores. Streptomyces tendae has been found to make enterobactin, another sid-erophore.

There are several other actinomycete species that produce siderophores and engage in biocontrol action. Some of them generate siderophores of the heterobactin type, including Rhodococcus and Nocardia. These siderophores aid in the formation of ferric-siderophore complexes, which scavenge ferric iron. Actino-mycetes generate siderophores of the hydroxymate type, which have the capacity to prevent the development of a range of phytopathogens. The pathogens die as a result of the actinomycetes Streptomyces rochei IDWR19 and Pseudonocardia halophobica scavenging iron from the rhizosphere soil environment.

Several kinds of plants, including Cicer arietinum L., Lens sativum, and Vicia faba each have rhizospheric soil that contains several actinobacterial strains. Numerous types of antibacterial components that the majority of these actinomycetes are known to generate point to their potential use as biocontrol agents. Additionally, the majority of the actinomycetes isolated from these plants are capable of producing siderophores and phosphate-solubilizing enzymes, which aid the affected plants in enhancing their soil nutrient absorption and, therefore, yields. Phytophthora, Pythium irregulare, and Botrytis cinerea were among the pathogens that were reduced when a mixture of Streptomyces species strains was administered to seeds prior to planting. These studies likely imply that co-inoculation of seeds with a particular mix of actinomycetes that have biocontrol activity may be effective in preventing a variety of plant diseases[8].

Actinomycetes are known for their biocontrol abilities as well as other traits including growth-promoting activity and siderophore production. These traits are not only found in cash crops like maize and wheat, but are also very prevalent in fruit crops like guava. Streptomyces species resemble S. CANS, S. Frostae, and S. The author is S. In guava rhizoshere soil, Cinnamonensis and Leifsonia poae are significant flora. Guava seedlings allegedly saw a significant increase in plant height and dry matter after being infected with a mixture of these Streptomyces cultures. Studies showed that the culture mixture of Streptomyces generated phytohormones such auxins and Gibberllic acid along with chitinases, siderophores, and phosphate mobilizing enzymes.

Crop plants are susceptible to secondary infectious agents like nema-todes, which are often present in soil, in addition to primary pathogens like bacteria and fungus that infect them. Numerous strains of Streptomyces are also known to have excellent antagonistic effects on nematodes. Infection with Streptomyces sp.

The nematodephagous strain CMU.MH021 is well recognized for having the great potential to reduce the egg hatching rate of nematode pathogens like Meloidogyne incognita, while also successfully promoting plant development by creating IAA and hydroxamate siderophores.

Production of Hydrogen Cyanide

Production of hydrogen cyanide is another way actinomycetes function as a potential biocontrol agent. Numerous Streptomyces species have been shown to create HCN, which prevents respiratory phytopathogens from using their terminal electron acceptor in the electron transport chain system, hence preventing their development and survival. Furthermore, indications that actinomycetes produce HCN improve the solubilization of phosphate and other minerals, increasing soil fertility, are very promising.

Lytic Enzyme Production

One of the ways actinomycetes demonstrate their functions as biocontrol agents is by secreting an infinite number of lytic enzymes. These lytic enzymes cause infections and the cell wall components to disintegrate. For instance, the exceptional and effective biocontrol activity of several strains of actinomycetes, such as Actinoplanes phillippinensis, Microbispora rosea, Micromonospora chal-cea, and Streptomyces griseoloalbus, can inhibit Pythium aphanidermatum, the causative agent of damping-off disease in cucumber seedlings. It was discovered that each of these actinobacterial strains produces large amounts of -glucanases with the capacity to lyse hyphae of the fungus pathogen. Some strains may parasitize the oospores of pathogens, while others can create diffusible inhibitory metabolites. In the same way, Streptomyces sp. Another strong strain with broad-spectrum antifungal abilities is 9P. This strain secretes many important hydrolytic enzymes like chitinases, glucanases, and cellulases along with lipases and proteases, enabling it to inhibit a range of fungal phytopathogens like Alternaria brassiceae, which infects plant belonging to Brassica species; Collectotrichum gleosporioides, a common pathogen of perennial plants; Rhizoctonia solani, a pathogen with wide host range; and Phytophthora capsici, pathogen affecting peppers and other commercial crops.

Other than cash crops, there are several agricultural plants that improve the farmers' and agriculturists' economies. These consist of fresh produce. Due to their texture, nutritional value, and other factors, fruits and vegetables are presumably more susceptible to bacterial, fungal, and viral illnesses, which results in significant economic loss. Natural and environmentally benign biocontrol agents are urgently needed given the problems with the environment and the growth of disease resistance to pesticides. Due to their capacity to create volatile chemical molecules, microorganisms like actinomycetes have attracted a great deal of attention in this specific setting. Actinomycetes are considered good biocontrol agents with regard to this aspect because they show broad range antifungal activity and can control and sometimes prevent a variety of plant diseases. Although it is known that many soil inhabitants produce these compounds with antifungal and antibacterial properties. These organisms are utilized as a powerful biocontrol agent above other conventional agents due to the capacity of actinomycetes-derived volatile organic chemicals to penetrate quickly through the soil particles and cause significant morphological damage to the attacking pathogens.

This statement is supported by a number of studies. For instance, Streptomyces globisporus JK-1 has been found to create volatile organic compounds that have been shown to have significant antifungal action against Botrytis cinerea, a disease that affects numerous plants including tomato and tobacco. Similar to this, Penicillium chrysogenum and Botrytis cinerea's spore germination is reported to be inhibited by Streptomyces coelicolor. Volatile chemical compounds from Streptomyces philanthi may readily destroy Fusarium moniliformei's pathogenecity. Volatile organic chemicals produced by Streptomyces fimicarius BWL-H1 may be simply used to combat the other fungus Peronophythora litchii that causes litchi downy blight. According to studies, Streptomyces fimicarius generates 32 distinct volatile chemical compounds, with phenyl ethyl alcohol, caryophyllene, -copaene, and methyl salicylate being some of the most significant ones. Studies demonstrate the full inhibition of hyphal development by volatile chemical compounds from Streptomyces, such as methyl 2,4,6-trichlorophenyl ether and methyl 2-methylpentanoate. Additionally, the 2-methylisoborneol and trans-1-10-dimethyl-trans-9-decalol volatile chemical molecules generated by Streptomyces species are responsible for the distinctive earthy smell of damp soil.

Function as Plant Stress Reducers

A variety of variables, both biological and non-biological, affect agricultural output. The genetic make-up of the crop plant is one of the most essential and critical variables that affects crop production. The genetic make-up of a particular plant determines its productivity and consequent yields, its capacity to fend off disease-causing pathogens, and its ability to withstand various abiotic stresses like water scarcity, salinity, and drought conditions. Therefore, it is evident that a plant's genetic composition is both a strength and its biggest weakness in the agricultural industry. Fortunately, genetic engineering has made great strides in the understanding and tools necessary to keep these restrictions in check.

Obviously, only when even non-biological elements like average rainfall, humidity, and soil nutrition are present within the favorable parameters considering the genetic composition of the plant have new and improved crop varieties helped to alleviate these problems. Despite plants' inherent capacity to withstand environmental stresses from outside sources, non-biological causes may sometimes reduce crop output and cause stress to plants. However, we have been given access to a wide range of microbes with extraordinary abilities while being cognizant of the force of nature. These native creatures are natural mitigating agents for plants against abiotic stress because they have evolved to be able to survive in a range of challenging environments. Animals, including humans, have a particularly special bond with microbes. Plants and microorganisms have shown strong interactions. In fact, interactions between plants and microbes are regarded as crucial and essential to an ecosystem. Both parties are thought to gain from this kind of integrated interaction between microorganisms and plants.

The rhizosphere of a plant provides a special habitat for the microbial population, and the microorganisms provide a variety of advantages for the plant. In addition to supporting general growth, they are also thought to provide protection against a variety of abiotic stress situations[9]. Numerous stressors, such as biotic and abiotic stress, are continually present for plants. Plants exposed to high salinity conditions, infections from numerous diseases, including nematodes, attacks from pests, scarce water supplies, and stress brought on by heavy metal pollution are a few of these stress factors. Fortunately, plants have developed a response system that allows them to cope with all of these stressors; the system used ultimately depends on the kind of stress. In addition to the variety of secondary metabolites that plants make to support their metabolism, their roots also secrete an essential combination of substances into the root-soil interface, including organic acids, amino acids, and sulfates. The relationship between the rhizosphere bacteria and plants starts here.

In response to stress, the microbial population burden in the plant rhizosphere interacts with the roots and produces ethylene, a plant hormone essential for general growth and development, in significant amounts. Plants produce ethylene in two stages that follow one another. In the first stage, less ethylene is produced, which allows the plant to detect stress and react more subtly. However, such high levels also prove hazardous to plants, which may be visible in the form of reduced productivity, yellowing, and falling leaves, etc. The second subsequent phase of the ethylene peak helps the plant overcome the stress. Actinomycetes, a type of plant growth-promoting bacteria, produce 1-aminocyclopropane-1carboxylate deaminase at this point, which degrades ethylene into a non-toxic low molecular weight compound while still leaving just enough ethylene in the system to relieve stress and stimulate growth.

Resistance to the Toxicity of Heavy Metals

Man has come to understand the importance of environmental challenges as a result of industrialization and the continued usage of dangerous chemicals. The environment and ground water resources have been seriously impacted by the indiscriminate use of chemicals containing heavy metals in industry and the untreated discharge of toxic industrial effluents into water bodies. Humanity has suffered greatly as a result of heavy metal contamination of the land and water supplies. Naturally, a few heavy metals, including as zinc, cobalt, iron, and chromium, are regarded as critical micronutrients required for the development of plants, microbes, and animals. However, their presence at even millimolar quantities of their permitted limits is very harmful to all forms of life. They have a number of devastating impacts on living things, such as chromosomal abnormalities and slowed development. Typically, heavy metal contamination stress in soils exposes plants. Although plants have built-in defenses against such stressful situations, these defenses can only go so far.

The capacity of certain soil-borne microorganisms, such as actinomycetes, to collect or eliminate heavy metals from soil makes them a particularly effective heavy metal stress reliever for plants. Actinomycetes are inherently resistant to a variety of heavy metals. It has been observed that the primary and most significant genera of actinomycetes, namely Streptomyces, have an effective bioaccumulation and bio sorption mechanism for heavy metals. This significant actinomycete property is essential for the biological removal of heavy metals from damaged or polluted soils. Without a doubt, actinomycetes may be seen as renewing agents for the growth of sustainable agriculture. A variety of significant actinomycete representatives are essential to the maintenance of good soil. Actinomycetes have a variety of traits that support plant development even in unfavorable environmental situations. The urgent need is for the identification of competitive and efficient actinomycetes strains.

To lessen the financial burden of isolating and cultivating single function variations, it is also necessary to identify multitasking actinobacterial strains. Such an actinobacterial consortium will increase productivity by ensuring that plants are better equipped to absorb nutrients that encourage growth. Additionally, it is necessary to assess the effectiveness of these actinobacteria-based Biofertilizers across a broad spectrum of crop varieties. It goes without saying that certain cutting-edge scientific techniques must be devised in order to further enhance these creatures' dynamics. Actinomycete-based Biofertilizer standards may be raised by using a variety of cutting-edge biotechnological technologies. The shelf life, possible carriers' background checks to verify the credentials of actinomycetes, and therefore the economic ramifications must be examined before exploring methods for their mass production. It is important to properly address the issue of raising awareness of the concept of biofertilization and its advantages over chemical fertilizers. Most importantly, it is difficult to convince end users to switch from conventional chemical fertilizers to safe, eco-friendly Biofertilizers.

CONCLUSION

Actinomycetes have received a lot of attention in recent years due to their ability to impact plant growth and stimulate plant development. The primary elements that allow them to endure a range of challenging environmental circumstances are their interdependence on a variety of plants and association with important soil residents. Future agricultural techniques may benefit from exploiting and using the extraordinary abilities of actinomycetes to generate a healthy and supportive environment. They play important roles in recycling nutrients, protecting plants from infections and abiotic stressors, and encouraging plant development, all of which ultimately aim to produce healthy agricultural plants and hence increase yield. Actinomycetes also have the ability to remove dangerous and damaging heavy metals from soil, which helps to preserve the balance of the soil. Actinomycetes may be used as possible biocontrol agents in agriculture due to their ability to create a variety of secondary metabolites, including wide range antibiotics, lytic enzymes, and volatile compounds. The production of extracellular degradative enzymes and agro-active chemicals by these organisms is a dominating and fundamental characteristic that is effective in the production of humus and compost. The multitasking actinomycetes and their capacity to impart many benefits over plants make them an effective tool for alternative agricultural methods, which may replace toxic pesticides. It is clear that all of these characteristics of actinomycetes are strong enough to concentrate our attention on these bacteria and consider them a viable and unavoidable option for sustainable agricultural production.

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CHAPTER 12

INFLUENCE OF CYANOBACTERIAL SPECIES' GROWTH PATTERNS ON THE PRODUCTION OF BIOFERTILIZERS

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ABSTRACT:

Fertilizers are crucial for increasing an agricultural plant's output. Every kind of soil requires fertilizer since no soil has every nutrient already incorporated. Synthetic fertilizer application will have several negative side effects in addition to having an immediate impact on plant growth and production. Utilizing Biofertilizers will reduce any negative impacts and improve the soil's fertility. One of the most well-liked Biofertilizers used to increase the productivity of various agricultural plants is cyanobacteria. The shape and growing conditions of cyanobacteria, their function as Biofertilizers, and the benefits of using cyanobacteria and soil nitrogen-fixing bacteria as fertilizers in comparison to synthetic fertilizers will all be covered in this chapter. Additionally covered in depth were the prerequisites for cyanobacteria's in vitro cultivation as well as the methods of gene transfer that contribute to their higher productivity.

KEYWORDS:

Biofertilizer, cyanobacteria, soil nutrition, in vitro growth conditions, gene transfer.

INTRODUCTION

With a polyphyletic and diverse community of simple plants like dinoflagellates and blue-green algae, microalgae are made up of a wide variety of holophytic bacteria. The discovery of cyanobacterial fossils indicates that life as we know it began on Earth some 3,500 million years ago. These photosynthetic gram-negative prokaryotes, known as cyanobacteria, are among the most important creatures living on the planet, with a total biomass of around 1,000 million tons. Since the earliest cyanobacterial species capable of conducting oxygenic photosynthesis inhabited the surface of the planet, the development of the modern aerobically respiring living creatures has been accomplished gradually over a vast period of 2 billion years.

Among the many phytoplanktonic associations, cyanobacteria, often known as blue-green algae, are some of the most studied organisms. It has been discovered frequently that they coexist in symbiotic partnerships with other fungal species and plants. As cyano in Greek means blue-green, the cyanobacteria were classified as a kind of algae and placed under the Cyanophyta division. The similarity between the rRNA of cyanobacteria and the chloroplasts of modern algal and plant species demonstrated that chloroplasts were inherited from ancient cyanobacteria, supporting the endosymbiotic hypothesis. These cyanobacteria have cellular inclusions that serve a comparable purpose to eukaryotes' plasmalemma, lamellae, and nuclear region. When these organisms photosynthesis, which is significantly more efficient than bacterial photosynthesis because it uses water as the electron donor and chlorophyll an as the primary pigment, they produce phycocyanins, or phycobilins, a blue pigment that is water soluble.

These cyanobacteria are often used as natural indicators in water bodies because to their capacity to self-regulate their buoyancy and their great sensitivity to light. Temperatures between 45°C and 70°C and a pH between 7.5 and 10 are good for cyanobacteria growth. This characteristic may be completely used to increase the amount of carbon, nitrogen, and phosphorus in salt-affected soils while lowering the salinity. Additionally, they are essential in improving the poor soil quality that exists in many arid and sub-arid environments. Although these organisms' internal physiology and structure are similar to those of bacteria, the presence of photosynthetic pigments and enzymes causes their photosynthetic mechanism to be more like that of aquatic plants. The absence of an outer chloroplast membrane, thylakoid associations, cyanophycean starch, and cell walls made of a matrix of peptidoglycan are some of the traits that set cyanobacteria apart from other major algal groups like diatoms, brown algae, and red algae. The two main morphotypes of cyanobacteria are filamentous and unicellular forms. Both of these types produce structures that may be spherical in appearance or have irregular shapes, such as the colonies seen in Microcystis and the filamentous bundles seen in the genus Aphanizomenon. These filamentous forms are notable for their capacity to endure adverse environmental conditions including cold and drought by developing specialized spore phase differentiated cells known as akinetes[1].

Cyanobacteria Habit and Habitat

Cyanobacterial species may be found in a wide variety of settings, such as marine, brackish, or freshwater ecosystems. They often flourish as mats, free-floating planktonic forms, or as periphyton, such as Lyngbya, which is found clinging to different surfaces. One such cyanophyceae member, Oscillatoria, thrives next to hot springs and can withstand temperatures of up to 62°C, aiding in the processes of nitrogen fixation and nutrient cycling. These cyanobacteria have a special characteristic that makes their dispersion worldwide. They can adapt to any soil type and flourish there. These cyanobacteria spread widely to form blooms that may either be floating like Pseudanabaena or found attached to the bottom of the water body like Phormidium during the summer, spring, and early autumn when the water temperature is high and there is a huge availability of nitrogen and phosphorous. Cyanobacteria either float on the surface of the water, forming what is known as scums, or they may directly sink to the bottom of the water body due to the presence of air-filled vacuoles or vesicles in their cells, which adjust their buoyancy, when their ability to remain in high nutrient zones for their survival is threatened by high-velocity winds or water disturbances. The cells of cyanobacterial species like Aphanizomenon, Microcystis, Nodularia, and Nostoc form blooms in nutrient-rich eutrophic water bodies under unfavorable conditions when insufficient nutrients, temperature, and light intensity are present. These species tend to degenerate and die, producing a musty odor and clouding the surface of water bodies, which results in the production of harmful cyanotoxins that cause complications like liver and neural damage

Morphology and Reproduction Techniques

Mucilage-based sheaths are principally responsible for confining the different shapes that cyanobacteria may take, such as filamentous, unicellular, or colonial forms. In filamentous bacteria like Tychonema, each cell is organized end to end to create trichomes that are encircled by mucilaginous coating. These cyanobacteria do not undergo mitosis in order to reproduce, in contrast to algae and other sophisticated multicellular organisms. Many species of cyanobacteria have non-motile, very hardy cells called akinetes that have thick, enhanced cell walls and a propensity to accumulate large amounts of protein-based reserves called cyanophycean granules, which eventually germinate to create what is known as hormogonia or trichomes. The most frequent method of vegetative reproduction found in cyanobacteria is the fragmentation of trichomes, which also entails differentiating specific cells to carry out duties for their proliferation. Uniseriate trichomes are those in which cell division happens perpendicular to the axial section of the trichome; multiseriate trichomes are those in the Stigonemataceae family in which cell division occurs parallel to the longitudinal axis. Hormogonia, which are the short, modified fragments of trichomes, may either emerge from the parental sheath as several trichomes or they can separate from it to create a new filament that glides. Based on the physical traits of the external sheath and the kind of cellular division outlined above, there are essentially two types of branching processes that take place: genuine branching and false branching. Stigonema is an example of true branching, which produces lateral branches. In contrast, Tolypothrix is an example of false branching, which produces divergent branches.

The heterocyst, which aids in the synthesis of ammonia, and the vegetative cell, which aids in reproduction and photosynthesis, are the two primary cell types found in the nitrogen-fixing filamentous forms of cyanobacteria. Numerous filamen-tous species of cyanobacteria, with the exception of Oscillatoria species, have specialized cells called heterocysts that serve as the primary sites for nitrogen fixation. These heterocysts, which are formed from vegetative cells, include several tiny openings at both ends of the cell known as microplasmodesms, which aid in the connection of the heterocyst to neighboring cells.

The thicker cell envelope acts as a barrier to the passage of gases into and out of these cells, while these tiny holes act as a conduit for metabolic byproducts to flow through. These heterocysts, which differ from vegetative cells in that they lack the light-absorbing phycobilin pigment and have a photosynthetic system that does not release oxygen, are more generally reducing in nature. In addition, the presence of thick, waxy layers in the cell envelope prevents oxygen from diffusing into the cell but allows nitrogen to enter, aiding in the process of nitrogen fixation. Heterocysts operate as an arena for nitrogen fixation by using the organic carbon supplied from neighboring cells as an energy source. This is because they provide a favorable internal environment for the activity of the enzyme nitrogenase, which is hampered by oxygen[2], [3].

DISCUSSION

Fertilizer's Function in Plant Growth

The nutrients that are necessary for a cell's healthy development and physiological operation are taken up by plants from the earth. Rarely do we find soils that have all the nutrients agricultural plants need. It occurs for a variety of causes, including soil erosion, which reduces topsoil levels and renders the land infertile. Farmers all around the world started amending the soil with fertilizers to boost crop output as a solution to this issue. A fertilizer is a material that contains nitrogen, potassium, and phosphorus. These three nutrients are essential for boosting the soil's nutritional status and providing it with all the nutrients it was previously deficient in.

When fertilizer is put to the soil, it nourishes it and stimulates plant development, producing the best agricultural yield possible. Additionally, it supports the soil's physical, biological, and chemical qualities, which are related to the soil's porosity, microorganisms, and pH, respectively.

Productivity is greatly influenced by the correct quantity of fertilizer being added. Nitrogen, for instance, causes poor leaf quality when supplied in low quantities yet inhibited development when applied in high quantities. Fertilizers may be roughly categorized into three groups: Biofertilizers, synthetic fertilizers, and organic fertilizers.

Artificial fertilizers

These are sometimes known as artificial or chemical fertilizers since they are produced of non-living substances. They are produced in factories with the use of cutting-edge technologies. It is not biodegradable and, in contrast to those made from natural sources, may be instantly absorbed by plants. It has both benefits and drawbacks. It is affordable, widely accessible, and simple to use. They are also manufactured in a variety of shapes, including pellets, granules, tablets, and spikes. Most significantly, little amounts may be used to get the highest output possible. Despite all these benefits, artificial fertilizers could have a few drawbacks that reduce their market worth. Some of the most common failures that might occur while using certain fertilizers. Since synthetic fertilizers are chemically similar to salt, using them excessively may have several negative effects on plants, including soil-water quality.

Risk of salt burn may be referred to as the sum of all these detrimental consequences. More than 30% of the minerals in the soil that are soluble in water are lost as a consequence of leaching, making it impossible for plants to use those elements for nourishment. Also, a situation called as eutrophication results from an overabundance of plants in water bodies that raises nitrogen levels. In addition, a number of chemical fertilizers that include acids like sulfuric acid and hydrochloric acid tend to degrade soil quality and increase its acid content, which further inhibits plant development. Because it is water soluble and found in fertilizer, iron has the potential to accidentally generate rust stains on concrete. The fertilizer's unneeded hardening and caking as a result of its tendency to absorb atmospheric moisture content is another significant drawback, underscoring the requirement for dry storage [4].

Natural Fertilizers

Farmers began employing organic fertilizers made from living things to get around these challenges. They come in a variety of forms, including compost, manure, and green manure. Compost is made from organic waste that has decomposed, while manure comes from animals like cows, chickens, goats, and many more. Growing plants, especially different kinds of legumes, are harvested for green manure. Although they function similarly to synthetic fertilizers in improving soil quality and yielding the highest crop output, they do not pollute the environment around them. They also help to improve soil composition, water retention capacities, and soil erosion resistance. Additionally, it aids in disease prevention by meeting the nutritional needs of the plant and boosting tolerance. But the sole drawback of organic fertilizer is the need for it in big amounts and its sluggish absorption into the soil. As a result, the farmers found it challenging since they had to buy a lot of fertilizer.

Biofertilizer

Compost and manure were used in traditional agricultural practices to provide nutrients to the plant. They lack the strength of synthetic or chemical fertilizers, which take effect right away in the soil. However, the widespread use of synthetic fertilizers led to environmental harm, contaminated water supplies, and resulted in the release of substances that cause cancer into the atmosphere. Later on, Biofertilizers were created as a fantastic replacement for conventional fertilizers in order to reduce pollution levels. In order to achieve optimal production, Biofertilizers increase the supply or availability of key nutrients by including live microorganisms. They are more affordable, environmentally beneficial, and practical for farmers to use. By solubilizing the insoluble phosphates and fixing atmospheric nitrogen, the microorganism utilized in Biofertilizers makes the soil fruitful. They put a number of ingredients into the soil that are necessary for plant development.

In the beginning, nitrogen fixation is the process by which nitrogen in the air is biologically turned into ammonia, which is subsequently transformed into other compounds like nitrates and nitrites by numerous microbes found in the soil. Azotobacter, Azospirillum, and Rhizobium species are a few of the important nitrogen-fixing bacteria found in soil. For leguminous plants like chickpea and soybean, Rhizobium, a symbiotic bacterium of the Rhizobiaceae family, fixes nitrogen. When these bacteria infiltrate the roots, they create root nodules, which spread outward and produce ammonia. Additionally, the presence of bacteria in the soil has a direct correlation to the presence of legumes there. Azospirillum species fix nitrogen on salts of organic acids, unlike Rhizobium, which does not develop any root nodules. Additionally, they penetrate the roots of plants like sorghum and maize to manufacture specific chemicals that aid in plant development.

Phosphate solubilizes are microorganisms that have the ability to dissolve inorganic phosphate compounds such hydroxyapatite, dicalcium, and tricalcium phosphate. Agrobacterium, Bacillus, Rhizobium, and Pseudomonas species are possible phosphate solubilizes. All of these bacteria that fall under the categories of phosphate solubilizes and nitrogen fixers may unquestionably provide nutrients like phosphorus, potassium, and nitrogen. But the need for micronutrients like zinc has always been quite high. It has been discovered that Bacillus species aid in the Solubilization of zinc compounds that are insoluble, including zinc oxide and zinc carbonate. These are the several microorganisms that are used as Biofertilizers for their distinct benefits.

Biofertilizer made of Cyanobacteria

The group of microorganisms known as cyanobacteria, or blue-green algae, has all three essential qualities of a Biofertilizer. They help to produce plant growth stimulants in the soil, solubilize phosphate compounds, and fix nitrogen to ammonia. When compared to other natural sources, utilizing cyanobacteria as Biofertilizer may produce large amounts of ammonia. Therefore, it was said that cyanobacteria were a more effective fertilizer than those that used other microorganisms. Blue-green algae include Anabaena, Nostoc, Plectonema, and Oscillatoria, to name a few. Only when soil nitrogen levels were low could cyanobacteria be shown to be actively fixing nitrogen. The nitrogenase enzyme needed for the nitrogen fixation process is inactive in nitrogen-rich environments. When ammonia with a 40 ppm nitrogen content is present, the nitrogenase enzyme's activity is still active. The activity of the nitrogenase enzyme to fix nitrogen as well as the development of cyanobacteria has been suppressed due to the toxicity of nitrogen as ammonia at 75 ppm.

Blue-green algae were able to tolerate nitrogen in the form of nitrate even at concentrations of 100 ppm without any negative effects. The most important component, organic carbon, is a deciding element to assess the soil's fertility or richness. Because inorganic fertilizers are used so often in states like Punjab and Haryana, the carbon supplies have been depleted, making the soil unsuitable for growing crops. Later, researchers De and Sulaiman showed that cyanobacteria, in particular, play a significant role in increasing soil organic matter. Due to the presence of a filamentous structure, they also contribute to the soil's increased porosity and generate hormones such auxins, gibberellins, amino acids, abscisic acids, and cytokinins. They help to increase the weight of the fruit and grain as well as root and shoot development and seed germination. They support the development of the rice crops by preserving and improving the soil's fertility. In addition to lowering general salinity and boosting the amount of phosphorus in the soil, cyanobacteria have several advantages for crops other than rice, including those of barley, tomato, and other vegetables.

They also inhibit the development of weeds. After nitrogen, phosphorus is regarded as the essential nutrient that a plant needs in the greatest amounts. The availability of phosphorus to the plant has increased with the use of cyanobacteria as a fertilizer because cyanobacteria produce acidic enzymes and metabolic products that contribute to increasing phosphorus content. In addition, as they develop through successive phases, cyanobacteria release a variety of macromolecules into the soil, including lipids, proteins, and carbohydrates. These molecules interact with the soil's particles and work to bind them together. Due to this characteristic, tiny microaggregates are created, which eventually coalesce to form clusters. These substances progressively form macroaggregates that control how well the soil is stabilized. Cyanobacteria also operate as a biodegrading enzyme and have the capacity to be unaffected by any environmental pollution. Nostoc linkia, Calothrix, and Anabaena are a few types of nitrogen-fixing blue-green algae that have been isolated from various agricultural and ecological zones because of their capacity to increase rice output. Azolla, a fern that grows in rice fields and other shallow water zones and aids in multiple cropping, is another plant species that coexists symbiotically with blue-green algae. Chloroplasts enable these ferns to live freely and produce their own nourishment. In addition to serving as a biofertilizer, these blue-green algae also create significant organic chemicals. By releasing phenolic chemicals during the lignolysis process, Anabaena and Azolla help produce spores. Paddy fields often use certain organisms as inoculants, such as Nostoc and Aulosira, which have the capacity to fix around 25 kg/ha of nitrogen.

However, Anabaena in association with the water fern Azolla may fix around 60 kg/ha during certain seasons. In addition to their symbiotic relationships with ferns, cyanobacteria also associate with bacteria, diatoms, mosses, and other organisms including marine sponges. Dry green algae may be grown profitably utilizing sewage and brackish water and can replace chemical fertilizers due to their high amount of macro- and micronutrients as well as other important amino acids. In addition to serving as a source of nitrogen, cyanobacteria also protect plants from hazardous pesticides and fungicides and aid to improve soil quality. According to a research done on Ethiopian soils, a cyanobacterial strain injected into lettuce plants may enhance the crop's overall output and development. The optimal use of cyanobacteria as Biofertilizers would minimize the heavy reliance on fertilizer employment and might further stimulate efforts for a sustainable environment if everyone has a common understanding of the activities of cyanobacteria.

Development of Cyanobacteria

Cyanobacteria were first cultured by growing in conjunction with the soil, which serves as a carrier. The rice fields must be supplemented with soil-based inoculums. The majority of farmers in the nation used this technique, which is also known as "algalization," due to its advantages in terms of commerce and ease. However, this approach led to significant levels of contamination and subpar inoculum quality. Glasshouses and lighter carriers like straw have been used in place of soil to solve the issue. It is now possible to produce inoculum in huge numbers using a variety of methods. The techniques of today are based on soil and straw, and the development of algae is medium-specific. They consist of the use of the pit, field, or trough technique, as well as the nursery cum algal production method. A flowchart is used to demonstrate the steps involved in the trough or tank approach. The pit technique involves digging pits rather than troughs or tanks in the ground, then covering them with thick polythene sheets to keep the water in. The rest of the process is identical to the trough approach except from this. Small manufacturers may easily use and operate this system for less money. It is advised to apply half a KG of the BGA Biofertilizer created to an acre of rice or any other growing area when it comes to application. It is advised to only use it after thoroughly mixing with soil. Only three to four hours should pass before reapplying bio-fertilizer. The rice crop may be fertilized with half of any synthetic fertilizer to get the best results. Numerous additional improvements are being made in production technology, the more secure establishment of an inoculation organism in various soils, and the ability to demonstrate their beneficial influence on various crop yields[5].

Cyanobacteria in Vitro Culture Techniques

Cyanobacteria often grow extremely slowly, making upkeep of their culture a laborious chore. Thus, a set of adequate and appropriate parameters must be met in order for cyanobacteria to produce the requisite amount of biomass under in vitro circumstances. The growth and composition may be impacted by these circumstances. Below is a list of some of the aspects that should be taken into account while cultivating cyanobacteria.

Both Macro- and Micro-Elements

The most important nutrient is carbon, which may be consumed in both inorganic and organic forms. Sugars, fatty acids, and amino acids are among of the substances that are thought to contribute to the formation of inorganic carbon species. In a culture medium containing 18% dissolved CO2, cyanobacteria may be grown. Temperature and pH both have a role in determining what type of nitrogen should be present. If the pH is high, ammonia will predominate. This nutrient may alter the biomass's composition. The macronutrient phosphorus is essential for development and serves as a growth inhibitor. Polyphosphate reserves are a way for cyanobacteria to store surplus phosphorous. Additionally, cyanobacteria need large quantities of other macronutrients such sulfur, calcium, magnesium, and potassium. For their in vitro development, micronutrients including molybdenum, iron, nickel, copper, zinc, cobalt, boron, manganese, and chloride are required.

Temperature

The photosystem II's capacity to evolve oxygen is greatly influenced by temperature, which also has an impact on the membranes of cyanobacteria and controls the availability of nutrients during absorption. The best temperature for the generation of biomass varies according on the genus and strain.

Density of Cells and Light

The major energy source for cyanobacteria development and for performing necessary metabolic functions is light. Up to the point of light saturation, cyanobacterial growth rates are raised with rising light intensity. The phenomenon known as photo-inhibition is caused by high light intensity. Mixotrophic cultures are more favorable because they are more metabolically active, needless light for development, and are less susceptible to light saturation.

Methods for Cyanobacterial Gene Transfer

The phylum of prokaryotes that is capable of oxygenic photosynthesis is known as cyanobacteria. These may be seen with the unaided eye, include pigments for light absorption, and are all around us. Genes inherited naturally or genes obtained via both vertical and lateral transfer mechanisms are required for the diversification of this kind of group. We must create or develop novel culture techniques and, for certain strains, genetic modification in order to boost their output. There are two different forms of transformation: chromosomal transformation and plasmid transformation. Since cyanobacteria have the unusual ability to spontaneously attach N2 to the environment, they have also been employed as Biofertilizers. Using genetic recombination, we may further modify these strains to include other resistances. As described, many gene transfer techniques are used to transfer genes into cyanobacteria.

Change Mediated by DNA

A marker with resistance to p-fluorophenylalanine in N is required for DNA-mediated transformation of auxotrophic valine. muscorum. N. Muscorum was grown in BG-11 medium and put through a series of purity tests. DNA was taken from an appropriate donor strain, then cloning was performed using either spores or single cells. Along with wild type, the development of the Val mutant was detected. Centrifugation was used to collect the recipient cells, and washing and suspension came next. DNA was added, then the mixture was exposed to light. The test tubes are chilled to stop DNA uptake before the cells are pelleted and incubated. According to the findings, the greatest number of transformants were seen between 8 and 28 hours into the exponential growth. Method for transferring from Gloeocapsa to N. the herbicidal resistance genes Basalin and Machete. Singh et al. completed the muscorum. Here, genetic cross was used in conjunction with Daniell and McFadden's transformation approach. Matr, Basr, Strs, and Mats, Bass, Strr of both strains are used in equal amounts in the crossing experiment. In contrast to the cross- and trans-formation produced by unicellular cyanobacteria, the findings of this transformation experiment indicated that DNAase activity had some influence. According to research, DNAase treatment 97% reduces the development of recombinants. The thermophilic cyanobacterium Thermosynechococcus elongates underwent a naturally occurring metamorphosis. Without causing any harm to the host genome, exoge-nous DNA was transformed into the cyanobacterial genome using the appropriate vectors, and a novel selectable marker for T was also developed. By enhancing the codons that make up the kanamycin nucleotidyltransferase gene.

Electroporation

High-intensity electric fields are used in this process to pierce the receiving organism's cell membrane and allow for the admission of large molecules like DNA. Numerous benefits include the ability to rapidly divide a large number of cells, great efficiency, the ability to employ non-competent cells, and simplicity. The shuttle vector pRL6 is delivered into Anabaena sp. via the electroporation technique. Using plasmid RP4 with a 2.5-ms time constant, strain M131 may produce maximal transformants at a field strength of 8 kV cm1. 250, 500, 750, and 1,000 V cm1 electric pulses were used for 2 or 4 ms to convert the Oscillatoria MKU 277 by introducing shuttle plasmid PRL489.

Conjugation

The process of transformation for filamentous, N2-fixing cyanobacteria that exhibit heterocyst development involves conjugation using a plasmid from E. coli to the many strains of cyanobacteria. Three plasmids are required for the conjugation process, and they are independent of the host and recipient. They are: Conjugal Plasmids: These carry the genes necessary for cell-to-cell communication and may regulate the timing of the other two plasmids. They can be of two types: big or tiny, like RP4 and pRL433. Helper plasmids: These plasmids, such as pRL518 and pRL623, code for methylase and mob genes, which are necessary for conjugational transfer, in order to circumvent the restriction endonucleases generated by cyanobacteria. The transfer is started by this plasmid. Transporting the appropriate DNA to the recipient is done using cargo plasmids. The presence of the bom site is one of this plasmid's key characteristics. Shuttle vectors, such as pRL6 with a replicon from cyanobacteria and E, are one kind of cargo plasmid. Coli and may be employed for novel gene expression and independent replication. In order to create knockout cyanobacteria using transposon mutagen-esis or gene replacement mutagenesis through homologous recombination, suicide vectors are utilized. The conjugation of the Anabaena PCC7120 strain makes use of RP4 and two other kinds of plasmids. Plectonema boryanum and Fremyella diplosiphon both use this technique.

Biolistic Approach

The majority of eukaryotic cells and tissues adopt this technique. This method uses micrometer-sized gold and tungsten particles that have been coated with DNA of interest. High pressure from a cannon or pressure gas is used to direct the particles into the cells. Instead of using gold or tungsten particles, bacterial magnetic particles with diameters ranging from 0.1 to 0.5 m are employed since they can bind far more DNA than the latter two. Synechococcus sp. was pSUP1021-coated BMPs were fired at. NKBG 15041 via particle cannon at certain speeds. It was observed that dry BMPs spread more readily than moist ones[6]–[8].

CONCLUSION

A major challenge for crop cultivation in terms of yield is the depletion of soil productivity and the increase in environmental contamination. Cyanobacterial Biofertilizers may complement chemical fertilizers, which would be advantageous economically. The physicochemical characteristics of the soil and the amount of biologically fixed phosphorus and nitrogen might both be improved with the application of cyanobacterial bio-fertilizers for rice crops. Additionally, some of these Biofertilizers also release growth-stimulating compounds that aid in raising grain output and quality. The most often used mechanisms for gene transfer among the several that have been developed are DNA-mediated gene transfer and conjugation.

In this instance, three different plasmid types collaborate to change the recipient organism into a transformant. The insertion of a foreign gene into that organism may be performed by using other techniques like electroporation and biolistic, therefore overcoming its inability to convert on its own. To find the most modern and effective transfer techniques, several experimental studies on biological processes like transduction are now being conducted. In addition, it is necessary to comprehend the ideal and standardized culture conditions, such as pH and temperature, for growing cyanobacteria in vitro in order to get desired results.

Since the dawn of human civilization, several physiologically active substances, including different colors, steroids, vitamins, amino acids, and carbohydrates, have been extracted from blue-green algae. These substances are now widely recognized as components of pharmaceutical and nutraceutical formulations. Due to their ability to create anti-microbial, anti-cancer, and anti-viral drugs, several of these secondary metabolites produced by cyanobacteria are significant medically.

By creating metagenomics clone libraries of cyanobacterial nucleic acids that have been screened for the presence of relevant genes, metagenomics also suggests itself as a workable solution to the problem of axenically growing cyanobacteria for the purpose of separating metabolites.

The idea of developing previously uncultivable strains of transgenic cyanobacteria with the ability to produce novel metabolites that may open new doors for the advancement of humanity as a whole attracted several researchers to this field, despite the fact that the use of these cyanobacterial secondary metabolites has advanced phenomenally.

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CHAPTER 13

APPLICATION OF BIOFERTILIZERS IN AGRICULTURE: AN EFFECTIVE ALTERNATIVE TO CHEMICAL FERTILIZERS

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ABSTRACT

The employment of advantageous microbial strains as a Biofertilizer is now being used to maintain crop development and production with healthy soil compositions and structure. Many farmers are now paying greater attention to the use of Biofertilizers in our agricultural sectors in an effort to reduce or eliminate the negative impacts of chemical fertilizers. In order to increase crop yield, many chemical fertilizers and other soil nutrients are added in current agricultural techniques, which has led to a progressive decline in the health of the soil. In order to maintain healthy soil conditions for agricultural development, people have created soil management procedures. In this context, cyanobacterial strains have been introduced as Biofertilizers for increased food safety and sustainable crop output. Rhizobacteria, and mycorrhizal fungal species, cyanobacterial strains, and other useful microorganisms are used as Biofertilizers in soil fertility maintenance to help improve nutrient uptake capacity, induce plant growth, and plant tolerance to biotic and abiotic stresses in soil. Additionally, the protection provided by Biofertilizer might help the plant's defensive mechanism. Additional Biofertilizer functions are attributed to the gene regulatory signaling network for cellular pathways or cellular reactions that aid in increasing crop output. The author will focus on the numerous elements that might lead to the creation of different kinds of Biofertilizers for crop enhancement.

KEYWORDS:

Biofertilizer, cyanobacteria, factors, soil, fertility, adverse effect, chemical fertilizer.

INTRODUCTION

Chemical fertilizer is manufactured from inorganic compounds, petroleum products, rocks, and other organic sources. It may enhance soil fertility quickly and has the notable benefit of producing the appropriate nutrients at a reasonable price. Chemical fertilizer is a product that can be modified on an industrial scale. It mostly consists of elements like nitrogen, potassium, and phosphorus in defined quantities or weights, and its usage has been linked to eutrophication processes in water bodies as well as air and ground water pollution. Recent attempts have been made to channel the production of nutrient-rich, high-quality food into a sustainable mode in order to confirm or increase biosafety. Innovative farming practices have been discovered to place more emphasis on the use of organic and biological fertilizers as an alternative to synthetic or agro-fertilizers. It has been said that boosting fertilizer availability while preserving soil or field management might depend on organic matter input to improve soil fertility. In this respect, a novel method is used to ensure food safety and improved soil biodiversity, which may gain extra benefits from the use of Biofertilizers[1], [2].

Dependent on the existence of the natural soil microorganisms is organic farming. Rhizobacteria are a specific kind of fungus that have the capacity to promote plant development. By aiding in the N2-fixation process and the Solubilization or mineralization processes of P or K elements in soils, the Biofertilizer may maintain optimal health conditions while also maintaining a more nutritive soil environment. Both the creation of antibiotics and the release of growth-regulating substances may be induced or promoted by these activities. Furthermore, Biofertilizer given to the soils is claimed to cause the biodegradation of organic substances or materials. Biofertilizers may be applied to soils as inoculums, and they can participate in nutrient cycle processes to multiply, which will increase crop yield. When chemical fertilizer is supplied to soil, it has been claimed that 60% to 90% of the entire amount applied leaches beyond the soil's surface and that any remaining chemical fertilizer is used by plants to grow. There are several microbial strains that are employed as Biofertilizer microbial inoculums with potassium or potassium solubilizing microbial strain as well as mycorrhizae, including Azotobacter, Azosprillum, Rhizobium, and Cyanobacteria. These strains, which belong to the so-called PGPR group, have been seen to multiply in soil below or below without any tillage material or least tillage treatment. Effective strains of the bacteria Azotobacter, Azosprillum, Phosphobacter, or Rhizobacter may assist in providing the N2 element to certain plants, such as Helianthus annus, which assisted to increase the height of the plant by increasing the number of leaves and stem diameter. Furthermore, the treatment of these strains has been observed to increase seed dry weight and seed filling capacity by %. These Biofertilizers have a positive impact on rice crop physiology and increase root morphology when applied to the soil as Azotobacter, Azosprillum, or Rhizobacter [3], [4].

DISCUSSION

Biofertilizers are organic substrates that contain helpful bacteria. By increasing the delivery of nutrients to plants, these substrates have assisted in stimulating the development of plants or trees. Mycorrhizal fungus, blue-green algae, microalgae, and bacteria are among the microbial strains found in Biofertilizer. It has been discovered that cyanobacteria display the potential to fix nitrogen and that mycorrhizal groups of fungus have the capacity to preferentially with-draw minerals from organic materials for plant development. Dinitrogen molecules are transformed into nitrogen compounds during nitrogen fixation, and certain bacteria are also capable of changing soil phosphate from insoluble to soluble forms. One example of a crucial symbiotic nitrogen-fixing bacteria that may take food from plants for shelter and then provide plants its fixed nitrogen is called Rhizobium. Azospirillum is a different kind of nitrogen-fixing bacterium that lives in the roots of higher plants without ever becoming a part of them. It is referred to as rhizosphere association with collecting of plant exudate that is utilized as food by them.

Associative mutualism refers to rhizosphere association activities. Cyanobacteria have been seen to coexist in symbiotic relationships with a number of plants. According to reports, Anabaena species, which are located in the fern's leaf cavities, are nitrogen-fixing cyanobacteria. It has been discovered that fern plant death may release it, and rice plants can use its residue without any restriction on plant development. It has been discovered to be a free-living soil bacterium that fixes nitrogen. Saprotrophic anaerobe bacteria like Clostridium, Beijerinckii, Azobacteria, or Bacillus polymyxin are employed as Biofertilizer inoculums, and Azobacteria and Azospirillum are two often utilized microorganisms in the creation or synthesis of biofertilizer. Trichoderma, which was separated from natural sources into four different species or strains, is used to create Biofertilizer. After 30 days of treatment, it has shown some positive effects on plant growth and development, including faster seed germination, increased plant height, fresh plant weight, and higher crop yields when compared to control plant growth profiles[5], [6]. With this Biofertilizer for 30 days compared to control, further improvements in soluble sugar, soluble protein, and chlorophyll contents are recorded in the same plants. Nitric acid content appeared in much smaller amounts in the blue region compared to the control plant surfaces, and it has been shown that Biofertilizers may improve the Chinese cabbage plant's ability to tolerate environmental challenges.

Enhanced urease enzyme, phosphatase, and catalyze enzyme activity in soil environment with provision of more inorganic N and P element with decrease of harmful effects to flowering Chinese cabbage is documented at 30 days of treatment. Trichoderma was used as a biofertilizer, which boosted Chinese cabbage's quality, antioxidant activity, and yield while also improving nutrient absorption and stress tolerance. Additionally, this biofertilizer enhanced or stimulated the development of the plants or crops as well as the yield of the cabbage plants while retaining the quality of the soil [7].

An excessive amount of biofertilizer may minimize the need for chemical fertilizer while also reducing environmental damage. Trichoderma-enrich biofertilizer has a variety of documented effects. For instance, the effects of BioF/compost, which contained household or kitchen waste with Trichoderma harzaianum T22, and BioF/liquid, which contained T. harzaianum T22 strain culture in liquid nature media solution, were examined in field trial studies to see how they affected the growth profile, yield capacity, or nutritional quality of Lycopersicon esculentum.

Synthetic Fertilizers

Chemical fertilizers include high concentrations of several important elements in the form of compounds, which are necessary to promote plant development. This fertilizer, which is used in greater amounts as nutrients for plant development, contains the three essential components C, H, or O in its structure or composition. Primary, secondary, and micronutrients are the terms used to describe plant nutrients. Ammoniacal nitrogen, nitrate nitrogen, and amide nitrogen are all types of nitrogen found in the category of nitrogen fertilizer. Phosphoric fertilizer, which includes phosphate in its many accessible forms, is another kind of chemical fertilizer. Muriate, a fertilizer that contains potassium, and potash sulfate contributed to the soil's K deficiency. Groups of fertilizers exist. Farmers may sometimes employ complicated or mixed chemical fertilizers that can assist soil by supplying many nutrients. Food production often uses chemical fertilizers, and the expansion of these sectors depends on the availability of efficient forms of the many nutrients needed for crop development. Chemical fertilizer production and use have a greater negative environmental effect due to their inefficient functioning. Chemical fertilizer residue is released to the environment, especially water sources, due to increased rates of fertilizer manufacture and use on cropland. Therefore, appropriate methods or techniques for a healthy environment may be identified for successful management in the fertilizer business. It is required for some useful recommendations about the use of control measures and prospective waste reduction strategies.

For the development of the nation, the Indian government has implemented a number of processes to provide financial rewards or assistance to farmers. These actions are described below. By providing financial aid for the construction of biofertilizer synthesis facilities or units, government agencies like NABARD were able to promote the manufacturing of these fertilizers. The subsidy was paid at a rate of 25% of the overall financial advantages or aid, up to a maximum value of Rs. 40 lakhs. They have also backed financial assistance or rewards for farmers who promoted biofertilizers via the integrated plan for supports to crops of oilseeds, oil palm, and maize crops, up to 50% of total cost or Rs. 100/hectare rate.

According to reports, they offered a financial aid of Rs. 150 per acre as part of the National Food Security Mission's program to speed up the production of pulse crops. The government has also supported a program for financial advantages or aid to encourage producers of organic biofertilizers to build up manufacturing units or facilities in accordance with the following guidelines.

Individualized Fertilizers

It has outlined some objectives for promoting site-specific nutrient management practices in order to maximize the effectiveness of chemical fertilizer use. These chemical fertilizers are described as multi-nutrient sources with carriers that are intended to contain micro- or macronutrient elements sources for application in soil to support crop growth. This information is based on results from soil tests that were used to formulate nutrient combinations. The Department of Agriculture and Cooperation has been assessed for the effects of the 25 fertilizers in this promotion of tailored fertilizer via soil testing.

Enhancing Fertilizer

Biofertilizers Application of fertilizers to plants in agriculture. Numerous living things, including bacteria, blue-green algae, and mycorrhizal fungus, are documented. Mycorrhizal fungi demonstrated their capacity to remove the minerals needed for plant development from organic materials. By offering a highly effective alternative to chemical fertilizers in the current agricultural sector and sustaining soil health, effective and compatible microbial strains may be used for biofertilizer manufacturing jobs. The processes or procedures used to generate biofertilizers are currently pricey. However, the use of biofertilizers in agricultural cultivation may increase crop output while guaranteeing food safety. For effective biofertilizer development in agricultural areas, a selection of microbial strains that have evolved plant growth stimulating ability and bacteria, fungus, or cyanobacteria are used. Numerous in-depth studies on the manufacture of biofertilizers have been conducted in this respect, supporting the knowledge for optimum crop output. The use of biofertilizers in agricultural production may increase crop output and food safety while promoting plant development via a number of processes. Additionally, it has offered protection against many plants. Biofertilizers have shown important functions or effects and their use in many different fields. Microbial bioagents may be used to control chemical fertilizer, and they have been proven to be eco-friendly crop management program components. Due to their impact on microbial growth patterns and dependence on several biotic or abiotic aspects or circumstances, it has shown the main issues of inconsistency nature during its implementation in the field. Several different microbial strains use these aspects of soil composition or structure as a biocontrol agent against plant diseases.

It has been observed that a number of different microbial strains may act as biocontrol agents to prevent plant diseases. Due to their inconsistent efficacy as a biocontrol agent, agricultural fields have shown restricted use, and sometimes they have reported unanticipated outcomes or results because of diverse soil conditions. It has been discovered that using two or more different microbial strains to combat plant infections is effective. These powerful microbial strains may provide the best possibilities for enhancing the effectiveness of biocontrol agents against diseases in their natural habitats in the soil. In soils and roots, the rhizosphere relationship may provide an interface to support microbial activity as a hub center. It may provide the best tools for understanding how different microbial strains interact with pathogens in host rhizospheres and act as biocontrol agents. By promoting plant development and levels of induced or improved resistances that may be identified by employing microbial strains, the rhizosphere can display direct antagonistic behavior.

This microbial strain is said to have a wide range of substrate consumption efficiency, the capacity to alter the rhizosphere and other existing banks, and the ability to manage the pathogen via antagonistic behavior. Endophytic bacterial species that are associated with plants have been shown to fix atmospheric nitrogen, aiding in the improvement of plant development. Diazotrophic bacteria inoculations may also provide substitute possibilities when N-fertilizer requirements are reduced. Understanding the interaction between plants and microbes is also necessary for the development of bacteria-based fertilizers. Advanced research projects are examining the morphological traits of the microbial MYSP113 and assessing how well it interacts with strange plants. The mechanism of processes that promote plant development together with their interactions required to be studied. In this context, two sizable groupings of bacterial strains with antagonistic natures are often used in microbial systems against plant diseases.

According to reports, some bacterial strains secrete antibiotic compounds or have other antimicrobial properties that may prevent the development of pathogens in crops. The Bacillus species or strains may secrete antibiotics that can be used to stop the development of harmful organisms. Chemical pesticides and fertilizers have been used in agriculture over the past several decades to increase crop yield. Their unique characteristics or traits include rapid, generalized activities, less costly or low cost production and storage, which is convenient for farmers. Resistance cultivars are the most cost-effective and long-lasting ways to manage plant diseases as they develop, and they may be used to accelerate or enhance the process by applying inoculums of microbial strains. The kinds of biofertilizer are as follows.

Biocompost

It is an environmentally friendly biofertilizer made out of sugar industry waste materials that have been given time to decompose. It is enhanced by fungus, plants, and human-friendly microbes. Applying biocompost to the soil may help crop plants grow more sustainably and with improved oil plant health by providing a full or complete complement of nutrients. It has contributed to the provision of micro- and macronutrients with high levels of organic matter and microbial activity. Through an increase in the rate of chlorophyll production, this biocompost has improved the enzyme activities of plant development, which may lead to high fruit yield and quality. In fields treated with biocompost, the absorption of micronutrients has risen as a result of higher NPK levels. By reducing the cost of manufacturing, this biocompost is created from distillery effluents in agriculture. It has made it easier to reduce the burdens of pollutants on aquatic ecosystems. On the development of potato plants, the impact of applying biocompost has been recorded. It has been shown that applying biocompost to a field may slightly alter the amount of copper, iron, manganese, and zinc relative to chemical fertilizers. The development of many sorts of plants, horticulture, or decorative plants is said to be aided by this biofertlizers agent, which is said to be nonpathogenic and environmentally beneficial. For pest control and plant growth promotion, the primary plants that employed Trichocard type fertilizer were paddy, apple, sugarcane, brinjal, maize, cottons, and vegetables. This biofertilizer functions as a killer of eggs of various bores, fruit, leaves, fruits eaters, or other diseases in the cropping field or as an opponent hyper parasite.

Trichogramma species are utilized in Trichocard forms of biofertilizer, and small-group wasps are the endoparasites of lipidopteran eggs. This species has shown significant benefits in displaying biological control agents, as well as their very tiny mature eggs, which render them inconspicuous to the untrained eye. On materials from reinfested packed goods, this species has shown the most effective agents for preventive and modality treatment. It has the capacity to deposit its eggs on a lepidopteran insect, which has prevented the damage to larval stages and killed the growing moth embryo before it laid its eggs. It was discovered that parasitoid larva are known to eat the inside of wasp eggs or pupae after they have been there for 7 to 14 days. One female wasp is demonstrated to be capable to parasitizing up to 50 or more eggs in her adulthood for a life span of 3 to 14 days. Adult parasitoids are known to mate in extremely brief periods of time following emergence. Trichogramma species have been seen foraging while walking on surfaces, and wasps have been observed releasing parasitoid eggs attached to cards by keeping them at temperatures between 8°C and 12°C at intervals of seven days. Before application to fields, Trichogramma species must be kept at 5 to 10 °C in an ice box or refrigerator. For various crops, later is sprayed three to four times at intervals of ten to fifteen days. Once eggs of hazardous insects start to emerge in fields that are tied in little pieces of cards immediately in various areas of the fields on the bottom surfaces of leaves or at joints of leaves or stems, it may begin to work as soon as possible. It may be administered in the evening to the fields at a rate of five cards per hectare for regular crops and ten cards per hectare for large crops. However, no chemical pesticides should be sprayed before, during, or after its application.

Azotobacter

This fertilizer plays crucial functions in N2 fixation and safeguards the roots from soil-borne diseases. According to reports, 75% of the atmosphere's total nitrogen content, or N2, is a crucial constituent or component of plant nutrients. The environmentally friendly nature of biofertilizer is discovered to be used as an alternative to chemical fertilizers in fish culture or aquaculture, and it has represented to represent an essential objective or target to reduce the water pollution and also enhanced the water quality by boosting the development rate of fishes. Azotobacter species are unattached, live microorganisms that have the capacity to fix N2. It has shown a number of favorable or constructive impacts on crop growth or production in the agricultural industry.

The biosynthesis of growth-regulating chemicals including auxin, cyokinin, and giberellic acid may aid in this. By enhancing nutrient intake and accelerating nitrogen fixation processes, it may protect plants against phytopathogens while also promoting the proliferation of rhizospheric bacteria. With several conditions, such as soil pH or soil fertility, it may increase the amount or population of certain bacterial species in the soil. Azospirillum brasilense and Azotobacterium chroococcum are two types of strains in the Azobacter species that have been shown to have an impact on inoculation mode or age. It is also reported on bacterial counts, water chemistry, specific growth rate, aspartate aminotransferase activity, alanine aminotransferase profile, and the mode of histopathological changes.

It has been reported that treatment of the Azotobacter microbial strain causes an increase in the profile of water activity analysis results, such as consumption of dissolved oxygen profile in cultivation media, biochemical oxygen demand profile, or chemical oxygen demand profile with nitrogen phosphorus profile, NO3-N, or O-phosphate group’s levels. In comparison to Azotobacter, levels after azosprillum therapy were lower. Additionally, it was stated that either a mixed or a single bacterial treatment might result in an increase in fish SGR. A mixed bacterial therapy is more effective than a single treatment in improving water quality measures, ALT and AST levels, and several histopathological lesions in fish. One inoculation of Azotobacter as biofertilizers may be concluded to be an effective probiotic and has been documented for usage in Orechromis niloticus aquacultures[8].

Phosphorus

The total nitrogen content of the soil is measured using phosphorus-based fertilizers, and occasionally the soil need both more and less nitrogen. The phosphorus was released into the soil, where it settled as clay particles. With the decrease of phosphorus deficit in plant growth, phosphorus may be discovered to contribute to or play a function in the growth and development of plants. According to reports, soil contains the complete amount of phosphorus in the form of inert organic or inorganic materials that is unavailable to plants. According to the research, many farmers could not afford to employ P-fertilizers in the event of a shortfall. As a result, it might provide a different method of supplying phosphorus. Phosphate solubilization microorganisms, which may assist in hydrolyzing the organic or inorganic insoluble phosphorus to soluble P form and can readily be digested by plants, are utilized for this phosphorus availability. These PSM group microorganisms are useful for overcoming P-scarcity and plant uptake in environmentally and economically sensible ways.

According to reports, this fertilizer contains organic materials that are good to the environment and contains vitamins, hormones, organic carbons, sulfur, or antibiotics that have helped increase crop quantity and quality. It has shown the ability of rapid fixing to increase soil fertility. Vermicomposts are said to be sources of essential organic materials that are leftover components of plant or animal origin. They are also said to have finely split earthworm coats and be created by non-thermochemical processes with biooxidation and organic material stabilization. This biofertilizer was created as a result of interactions between aerobic microbial strains and earthworms, as shown by the passage of this substance via the earthgut. With an enhancement in the soil's structure and increased nutrient and water retention capacity, vermicompost may give plants with the nutrients and hormones that promote development. There are reports of finding fruits, flowers, vegetables, and other plant products in vermicompost that is being grown or produced. It may contribute to healthier soil structures overall[9], [10].

CONCLUSION

The use of biofertilizer for crop development and production has been covered in this chapter. This biofertilizer is discovered to be environmentally benign and also simply assisted in giving plants the nutrients they need. It has given the soil fertility plant pathogen bio agents for a variety of crops, including sugarcane and cotton. This fertilizer has contributed to provide a substitute for chemical fertilizers that made issues with weed development in water bodies worse. Because 80% to 90% of chemicals are not used by plants and instead end up in water bodies, it helped to reduce pollution in water sources and caused issues for aquatic life. This chapter has described several microbial strains that have interacted with plants and assisted in the processes of nitrogen fixation. This chapter also highlighted the benefits and drawbacks of biofertilizers, which is one of the greatest options for a nation's food supply.

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CHAPTER 14

ASSURANCE OF BIOFERTILIZER QUALITY

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ABSTRACT

One of the key elements of sustainable agriculture and organic farming is biofertilizers. These enhance soil health and are inexpensive and environmentally friendly. Given that they are biological materials, their impact on plant development may not be as dramatic as that of chemical fertilizers. Due to the fact that even small-scale farmers can afford to purchase and utilize them, their utilization is very important in developing nations. Farmers are becoming more aware of biological fertilizers. However, the success of the biofertilizer inoculation depends on the kind of inoculants used. Therefore, it is crucial that the manufacturing of biofertilizers follow the quality control protocols to guarantee a high-quality product. Additionally, care should be made to remove any additional obstacles that biofertilizer technology faces. We should be aware that the microbial work force has enormous promise for the future if we employ biofertilizers in sustainable agriculture with reason.

KEYWORDS

Agriculture, Fertilizers, Microflora, Microorganisms.

INTRODUCTION

Biofertilizers are goods created by biotechnology using active organisms from the ecology of plants. These bacteria, which are found in soil and the root zones of plants, have the ability to convert inert nutrients into useful forms, increasing soil and crop production. These microorganisms use a pathway that involves nutrient mobilization, phosphorus Solubilization, and nitrogen fixation. These microorganisms are regarded as microbial fertilizers because they possess the ability to endure in artificial conditions with stable genetics. These bacteria remain viable for the duration of their shelf life because they are reliant on a carrier, which may be solid or liquid. These bacteria are used as biofertilizer because they can withstand various environmental and soil conditions. Due to the lack of quality controls and the oversupply of various efficiency products on the market, these biofertilizers first shown poor efficacy. The biofertilizers' ability to work had likewise been severely constrained. The biofertilizers were transported by lignite, maintaining continual sterility.

However, because of the extreme ambient temperatures, low temperature storage technologies must be used before being supplied to the fields. In addition to this, its longer preparation time than chemical fertilizers is a key drawback that limits its marketability. The biofertilizer was contaminated by other bacteria and never really contained the declared quantity and practicality. Biofertilizers underwent modifications to increase shelf life by including temperature-resistant varieties, consortia of inoculants, disinfected aqueous transporters, and better solutions. In addition, the government increased subsidies to manufacturing companies creating sterile aqueous inoculants and offered a subsidy if the created company effectively synthesized biopesticides. Therefore, these activities aided in the development of bio-fertilizers and guaranteed their use for 20,000 MT; nonetheless, quality issues continue to be a serious issue [1].

DISCUSSION

Biofertilizer Supply and Demand

The increased demand for natural products is thriving, not only because of the rise in discerning consumers but also because of rising incomes, improved farming practices that make organic products more robust, and rising wages. As a consequence, the increased demand for natural commodities is seen on a worldwide scale and has led to an increase in organic agriculture techniques. The size of the worldwide organic farming agricultural field area has increased from 37.5 to 57.8 million hect-ares. The aforementioned statistics indicate that the use of biofertilizers during improved natural farming practices increased soil fertility. Due to its natural composition and environmental friendliness, this has increased demand for biofertilizer food products. North America has over 28% of the global market share for biofertilizers. The United States has the largest share of these, accounting for more than half of the shares in North America. Due to its natural and environmentally beneficial qualities, the market for biofertilizers has grown in both the United States and Canada. However, the market for North American biofertilizers is only beginning to develop in Mexico. The many advantages of biofertilizers therefore lead to their widespread use, increased acceptability, and increased usage in sustainable farming. The market for meals made from bio-based ingredients has grown thanks to the nation's supportive attitude toward agriculture. owing to increased use of organic crops owing to nutrition and desire for high-quality food values, the North American region is anticipated to sustain its market[2].

Control of Biofertilizer Quality Procedure

To handle the microbiological goods in support of the customers, quality control is extremely important and should be continuously attained. The criteria used to determine quality are limited to the viability and conservation of the specific bacteria as well as the consideration of the available microbes. Finding control plots that lack current microorganisms but have a comparable composition to the final microbial products is crucial. Additionally, it is quite helpful that the biofertilizer exhibits the primary outcomes for top-notch management of the final biofertilizer goods. The biofertilizer's primary impacts are used as an indication. Additionally, the outcomes are included as guaranteed activities of the biofertilizer. Differentiating between the existing bacteria and the extra compositions on the impacts of the biofertilizer promised by the producer is a crucial criterion. The product is only an organic substance if the final results of the two experimental plots are comparable or cannot be statistically verified. This demonstrates that specific bacteria must be the starting point for the impacts of microbial products, and the objectives of the topics should be clear and instructive. As microbial products, biofertilizers act as nutrient providers and soil conditioners, reducing the agricultural burden and preserving the environment. For the sake of both enhanced agricultural output and the wellness of people or animals, high-quality soil conditions are crucial. As a result, the resources used to preserve high-quality soil conditions are considered ecological materials. However, as was already said, there are still a number of issues with regard to the use of microbial goods. In order to better serve the customers, quality control has to be more precise. Despite the fact that the effects of biofertilizers vary from country to country due to differences in the weather and soil environment, their importance for ecological preservation in the twenty-first century cannot be understated. In a similar vein, a range of biotechnologies should be recognized for boosting the effects of biofertilizers while taking environmental protection into consideration. Biofertilizers reduce the environmental impact of chemical substances. We share the same views on biofertilizers for biocontrol and bioremediation since we are a part of a community that is tied to the global food chain. The process design for biofertilizer quality control was shown in the following diagram.

Demanding Quality Control

The Government of India modified the Fertilizer Control Order in 2005 to put biofertilizers under statutory control in recognition of the urgent need to not only improve manufacturing but also produce higher quality biofertilizers. This reaffirmed the crucial guidelines that the manufactured biofertilizer product and manufacturing process would need to adhere to. The minimum shelf life, tolerance boundary, and requirements that must be met by various biofertilizers are specified. In the particular state, the applicable state directors of agriculture are responsible for enforcing the Act. They choose ground officers who can collect samples from producers, sellers, or farmers and send them to laboratories for analysis. The examination will be conducted by seven labs under the control of the federal government and eight laboratories under the control of the state governments. With orders to remove that batch, license suspension, license termination, legal action, and a fine or detention or both as penalties, action against the defaulter has been provided as a warning [3], [4].

Manufacturing facilities must adhere strictly to the regulations, and the examiner must monitor the product and the process. Penalties must also be applied to the debtor as a result. The market is swamped with biofertilizer products, some of which sometimes live up to the manufacturer's promises, but generally speaking these claims are not supported by the performance of the product, which makes the need for regulations and quality control even more vital. Farmers must continue to believe that biofertilizers are profitable, and it is the manufacturer's duty to ensure that the product that enters the market is of the highest possible quality. Although the government has now established rules and conditions, it is necessary to use force to ensure that they are followed because else the regulations are worthless. The authority in the area will have to train employees of the government or the standard approved body in the procedure necessary for the quality verification of the inoculums' production.

To complement the government examiner, other standard and specialized labs may be assigned to carry out quality verification. It should be ensured that the rules include both practice control and end product quality management. A practice run according to protocol would help any suspicions and corrective measures to be implemented promptly before further inoculum was administered. Such measures will ensure that the final goods, when they reach the market, adhere to the quality standards even during formulation and can firmly assert all the profits declared.Field displays should be set up using controlled, high-quality items, as well as the farmers' passionate labor, in order to build consumer trust in produced goods. These exhibits may be finished with the help of KVKs and other regional organizations, providing end users with additional quality assurance[5].

Requirements for Biofertilizers Quality Control Techniques for Testing

The common information, which is based on the authorized labeling on the biofertilizer container, should be verified first. This information includes the name of the biofertilizer, the crop for which it will be used, the methods used, the batch number, the date of production, and the date of expiration. The pH, physical properties, and moisture content of the carrier materials are then confirmed. Utilizing a variety of microbiological procedures, the estimate of the individual organism's microbial population must be assessed. Numerous morphological techniques were used to examine the colony morphology as soon as it emerged. Furthermore, the strains are identified in addition to their verification evaluation for strain validity using conventional microbiological methods.

The expansion of the quality assurance guidelines has drawn a lot of attention for research that has been devoted to increasing and enhancing the compassion of accessible approaches. The most popular methods for determining how much invasive or infectious rhizobia are present in inoculants created using non-sterilized processes are average plant contamination approaches. To provide the most accurate estimations of the amount of rhizobia in alfalfa inoculants, average techniques have been modified. Current research has significantly improved the typical plant infection method for counting rhizobia in the presence of other microorganisms by making specific options available to provide the customer more freedom.

Biological Techniques

Inoculant quality assessment has long been a subject of interest. Numerous microbiological methods, such as viable cell number, total count, plating, most likely number, and staining, have been used to ensure the quality of inoculants. It was determined that rhizobial counts were changeable despite the investigation into peat-based rhizobial inoculants for moisture, viable counts, pollutants, and effectiveness using plate counts and MPN; however, pollutants were present in nearly all of the inoculants, even in excess of the amount of rhizobia and disturbing inoculation efficiency.

When peat is not sterile, the MPN method is often used. Spread plate method just takes a little amount of time since cultivating plants is very important. This method is predicated on the idea that nodules will form on the roots if live rhizobia are injected on their specific host. Nodulation on that infected plant is evidence that infectious rhizobia are present [6]. Staining methods are used to keep track of the shape and size of the cells. Rhizobial cells are rod-shaped and adhere in groups of one or two. They don't appear in a lengthy chain. Pollutants are designated by long chains of cells. Gram-stained cells ought to appear red rather than violet. Fuchsin staining is a rapid and easy method. Fucshsin dye may be used to routinely examine rhizobial cells.

Serological Approaches

Serological techniques have been used successfully to regulate inoculant quality. Serological procedures include agglutination, gel immunodiffusion, enzyme linked immunosorbent test, fluorescent antibody method, membrane filter method, and others. In comparison to plate counting for selective enumeration, these techniques are more expedient and straightforward. Antibodies that have been raised against antigens found in microbial cells may be used uncontaminated or freely.

The frequent monitoring role of ELISA-dependent methods in medical and food microbiology applications is particularly valued.

Molecular Procedures

Recently, approaches backed by PCR, genetic markers, and probes have been used to identify strains. There were many fingerprint recognition techniques for microorganisms discussed. These procedures were used in conjunction with bacterial culture to prevent DNA isolation and to unite appropriate investigation via widespread use with computerization potential. Currently, primers are used to examine diazotrophic extracts, which are then subjected to fingerprint analysis. Patterns that are electrochemically split are very effective and conclusive. A variety of probes, including those for Azospirillum species, were created. New 16Sr-RNA targeted probes were created and made available for localization tests[7], [8].

CONCLUSION

Because they are living items, biofertilizers must be used carefully for the best results. Along with the use of artificial fertilizers and organic manures, their usage must be stressed. To ensure that the profits reported by the biofertilizers really reach the grower, the product's worth needed to be carefully examined. The government, research organizations, and local authorities must actively participate even though regulations and management acts are in place to ensure that the biofertilizers provide what they promise. In the same vein as the TRAI or any other successful example, an independent regulating agency is essential. In order to distinguish between the biofertilizer sector and the synthetic fertilizer sector, the government may also consider enacting an independent law found in the Biofertilizer Control Act.

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CHAPTER 15

CHARACTERISTICS, FEATURES AND APPLICATIONS OF BIOFERTILIZERS

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ABSTRACT:

An eco-friendly substitute for chemical fertilizer for sustainable agriculture is biofertilizer. By fixing nitrogen, solubilizing phosphorus and potassium, secreting siderophores, antibiotics, enzymes, antifungal, and antibacterial substances, and releasing plant growth-promoting hormones, the microbial inoculants aid in growth either directly or indirectly. These actions increase productivity and adaptability to deal with biotic and abiotic stresses. In the process of making biofertilizers, several microorganisms are used, including microalgae, arbuscular mycorrhiza fungi, Bacillus species, Pseudomonas species, Actinomycetes, Paenibacillus, and Cyanobacteria. For distribution as biofertilizers, the microorganisms are mass-produced at high cell densities and combined with carrier materials such lignite, coal, charcoal, filter mud, vermiculite, mineral soils, oils cakes, and coir waste. It would be more appropriate to optimize biofertilizer by coinoculating similar bacteria with similar bacteria, rhizobium with rhizobium, and bacteria with fungus, in order to increase growth and yield in terms of number of grains, number of leaves, shoot and root length, shoot and root fresh and dry weight, and other metrics. To increase the effectiveness of biofertilizers, researchers are developing novel genetically engineered microorganisms and nano-biofertilizers backed by research in bioinformatics, genome mining, and genome sequencing.

KEYWORDS:

Actinomycetes, Bacteria, Biofertilizer, Cyanobacteria, Fungi, Mycorrhiza, N-fixers, P-solubilizers.

INTRODUCTION

Due to the population boom, agriculture production is under even greater pressure to provide more and more food for rising bellies. The "green revolution" has been instrumental in creating high yielding cultivars and agricultural practices, which is crucial for sustainability. The "Green Revolution"'s monoculture methods, which included intensive field irrigation, the use of chemical fertilizers, pesticides, herbicides, and fungicides, have led to problems with soil deterioration, infertility of the land, high input costs, and pollution of the environment's resources. As a result, the idea of creating "green technology" has emerged as a way to discover fresh approaches to the continued use of natural resources without compromising their purity and stability. By causing eutrophication, soil acidity, and sterility, as well as weakening plant roots and erasing genetic diversity, chemical fertilizer usage has a negative impact on the ecosystem. Therefore, there is a great need to create technology as a substitute for chemical fertilizers in order to continue agriculture and preserve the interdependence of eco-systems and the environment.

Because the bacteria in biofertilizers solubilize soil nutrients, mobilize phosphorus, zinc, and potassium, fix ambient nitrogen, and release growth regulators in the soil, they are an excellent substitute for chemical fertilizer. In addition to the methods listed above, biofertilizers also assist plants in surviving stressful environments. Many of the organisms employed in biofertilizer have the ability to reverse their negative effects, which might help them resist metal stress[1]. As a result, they assist plants in developing stress resistance. The benefits of biofertilizers encourage their widespread adoption. These microorganisms, known as plant growth-promoting bacteria, have been used in agricultural production since the 1950s. However, owing to certain of their shortcomings, such as vitality, efficiency, adaptability, and inconsistency, their promise has not been marketed. Many initiatives have been made to get through these obstacles so that biofertilizer usage may be increased.

Biofertilizer Types

Biofertilizers are intrinsic plant microorganisms that are administered to the soil as inoculants to aid in the development of agricultural crops and ensure environmental sustainability. Rhizobacteria that promote plant development is given particular consideration in this context. They can fix nitrogen that would otherwise be unavailable to plants; they can mobilize and solubilize phosphate, potassium, sulfur, and iron; and they can indirectly aid in plant growth by eradicating pathogens by secreting siderophores, antibiotics, enzymes, or fungicides. These microbes of biofertilizers contribute to plant growth by producing growth hormones like auxin, cytokinin, gibberellic acid, and ethylene. Other microorganisms, such as actinorhizal nitrogen-fixing nodules and rhizospheric actinomycetes isolated from legumes, are known to encourage nodulation, aid in nitrogen fixation, and ultimately lead to plant development. These bacteria increase plant development by strengthening the contact between the plant and the microbe, but since they work independently, they are regarded as a distinct class of bio-fertilizers. This is conclusive evidence that this kind of relationship increased the effectiveness of biofertilizers, but the tripartite mechanism behind this link is still poorly understood. A vital component of an integrated nutrient management system in sustainable agriculture is biofertilizer. It is both environmentally beneficial and economically advantageous. Three main classifications of biofertilizer bacteria are made based on how they affect crop yield: i. by the control of the plant disease known as bio-protectant, ii, indirectly assisting in growth. Enhances the ability of biofertilizers to better absorb nutrients, and iii. Stimulates plant development. Stimulates plant growth by releasing biostimulants, which are phytohormones.

Applications and Characteristics of Biofertilizers

Biofertilizer made of cyanobacteria

General characteristics: Cyanobacteria, often known as blue green algae, are autotrophic organisms that can flourish in a variety of challenging environmental circumstances. These are mostly present in freshwater and marine ecosystems. These are primordial organisms that are often filamentous or unicellular in structure. Chlorophyll, carotenes, xanthophylls, c-phycoerythrin, and c-phycocyanin are only a few of the colors it contains. It has a variety of inclusion bodies for different purposes, including light-harvesting antennae, phycobilisomes, polyphosphate bodies, cyanophycin granules, polyhydroxyalkanoate granules, carboxysomes/polyhedral bodies, lipid bodies, thylakoid centers, DNA-containing areas, and ribosomes. Cyanobacteria employ cyanophycin to store nitrogen. Due to the presence of RuBisCo in its carboxysomes, this organism assists in fixing CO2. It is made up of two crucial cells: heterocysts, which fix nitrogen, and vegetative cells, which perform photosynthesis and support reproductive development. Extreme environments including high

UV intensity, temperature swings, high salinity, and desiccation are not a problem for it. Cyanobacteria evolved to have these characteristics during the course of evolution.

Nutritional qualities: Cyanobacteria are utilized as food supplements since they have a lot of nutritional components. Additionally, it has a lot of bioactive ingredients.

Cyanobacteria are the most basic organ-isms and are responsible for the current oxygen environment, which has evolutionary importance. It is regarded as the creature that gave rise to all plants. Due to its past life as an endosymbiont in eukaryotic cells, it also played a significant role in the creation of eukaryotic organisms.

Numerous applications may be made using cyanobacteria. 10 to 30 kg/ha of atmospheric nitrogen may be fixed. Pollutants may be broken down and soil fertility is raised. Additionally, it participates in biogeochemical cycles. Exopolysaccharides, which are produced because they aid in the formation of soil aggregates, boost soil fertility and water retention capacity. The CO2 is captured and turned into fuels. This may protect the environment from global warming by lowering the amount of carbon dioxide in the atmosphere.

Application: It is a powerful biofertilizer since it can fix nitrogen for plants. It is utilized as a dietary supplement because of its high nutritional content. On rice, wheat, tomatoes, etc., it has phytostimulating action.

Major effects: It creates sticky material that aids in the formation of soil aggregates, increasing the soil's ability to retain water. It also makes soil permeable. It raises soil biomass after death and decomposition, lowers soil salinity, inhibits weed development, secretes organic acid, and makes phos-phates accessible. It also releases phytohormones, vitamins, and amino acids. By absorbing heavy metals, it participates in bioremediation[2].

Crop: The following crop plants employ cyanobacteria as biofertilizers: rice, beans, barley, oats, tomato, radish, cotton, sugarcane, maize, chilli, and lettuce.

Biofertilizer preparation: Cyanobacteria are cultivated on agar slants to get their purest form before being used as a biofertilizer. A loopful culture is moved from agar slants to a 250 ml flask containing liquid medium and kept in a shaker for 3–7 days in order to expand its biomass. The mother culture or beginning culture is defined as having 105–106 cells per milliliter of the culture. These are then multiplied by ring-transfer to bigger flasks and maintained in a shaker until the cell count reaches 109–1010 cells/ml. At 4°C, they may be kept. For the manufacture of biofertilizer, a pH of between 6.0 and 7.5 is ideal. Fermenters are used to produce vast amounts of bio-fertilizer. With the aid of an automated filling equipment, liquid biofertilizers are packaged straight from the fermenter into 250, 500, or 1-L bottles. Packaging is done such that one-third of bottles are solely filled with biofertilizer and the other two are left empty to allow for aeration. The labels on bottles containing biofertilizer should always include the following information: the name of the inoculant, which identifies the microorganisms used in its preparation; the crop name; the application method; the date of manufacture; the expiration date; and others.

Because biofertilizers are carrier-based, a suitable carrier material must be used in their manufacture. The substances that contain microbial cells are the carriers. Some characteristics of a good carrier include being smooth and inert. The transport molecule has the capacity to take in water. It should be inexpensive, sterile, and easily accessible. Last but not least, it should have sufficient buffering capacity in order to maintain the pH of the created biofertilizer and keep it active. It should not include any materials that may solidify into lumps. The carrier molecule must be treated by mining, drying, and milling before being added to the biofertilizers. The price of biofertilizer increases due to this procedure. Peat, lignite, coal, charcoal, filter mud, vermiculite, polyacrylamide, mineral soils, vegetable oils, coir waste, and other materials may all be used as carriers. The most popular carrier molecule among the materials is peat, however India only produces a little amount of it. 108 viable cells per gram of carrier molecules is an excellent biofertilizer percentage.

According to its intended use, the particle size of the carrier material is also crucial. For seed coating, it must be between 10 and 40 microns, while for soil implantation, it should be between 500 and 1500 microns. Granular peat, perlite, charcoal, or soil aggregates are utilized for soil inoculation. Carriers need to be adequately disinfected before being utilized as inoculants. With the aid of calcium carbonate, its effects are also counteracted. The benefit of sterilization is that it prolongs the shelf life of biofertilizer. Carrier material is sterilized using either an autoclave or gamma radiation. Gamma radiation is the more appropriate of these two since it doesn't alter the physical or chemical characteristics of the carrier. After being placed within a polythene bag, the carrier is exposed to gamma radiation at a dose of 50 kGy. It delivers great efficacy and extends the shelf life of biofertilizer[3].

These are naturally occurring rhizospheric soil bacteria that are gram positive, have a high G+C ratio, are mostly aerobic but may also be anaerobic, and can operate as a biofertilizer by secreting several bioactive substances that include antibacterial, antifungal, antiviral, anticancer, and antioxidant effects. In addition, it can fix phosphate and creates plant growth hormones. These are naturally non-symbiotic free-living organisms. It comprises from 10% to 50% of the soil microflora. Due to its several beneficial roles, Streptomyces is a significant component of the actinomycetes. Numerous antibiotic compounds with antifungal characteristics are produced by Streptomyces. Blasticidin-S and Kasugamycin are two examples of medications that may treat rice blast disease. Mycelium, which is filamentous and branching and has an aerial component that resembles floccose, granular, or powdery, is how actinomycetes develop. Because it has traits from both bacteria and fungus, it is a transitional condition between the two.

Colonies are powdery and come in a variety of hues, from pink or yellow to white or gray. Colonies are hard, leathery, and difficult to choose. The presence of L-diaminopimelic acid in actinomycetes' cell hydrolysates is one of their distinguishing characteristics. A number of streptomycetes, including Streptomyces strains PC 12, D 4.1, D 4.3, and W1, have the ability to manage rice blast disease. These strains produce cell wall-degrading enzymes such protease, cellulose, and chitinase as well as HCN and siderophores. Streptomyces may lessen the severity of the illness by 35.6%–56.1%, as seen by fewer dried leaves and shorter lesions. The rice plant grows 40.34 cm taller thanks to the Streptomyces vaccination compared to the control. When compared to control, it also increases root length and dry weight by 15.43 cm and 0.8 g, respectively.

It is both an endophyte and possible biofertilizer for the rice plant. It increases grain and straw yields as well as the vegetative development of rice. It strengthens root. Because it secretes auxin and gibberellins, it encourages growth. It also serves as a solubilizer for phosphate. The growth of plants is improved when they are given 1 ml of pure Rhizobium leguminosarum by culture. Trifolii strain E11 and 20 kg of urea N-fertilizer per hectare. Additionally, for inoculation to the root, 1 ml of pure culture of the appropriate microbe should contain 1.34 108 colony forming units. When plants are fertilized only with urea N, their natural microbial diversity is reduced. A significant mutualism exists between the plant and the microbe, as shown by the plants' improved response to the application of endophytic microbes as a biofertilizer. Rice is a good example of a plant that harbors endophytic microorganisms that aid in its survival. However, frequent use of chemical fertilizers stresses the plant niche's natural microbial population by pressuring plants to grow more quickly. Chemical fertilizers disrupt the interactions between plant microbes and the natural microbial population of plant roots. Rhizobia sp. may be employed together with other rhizobacteria to improve the conditions for plant development. When this mixture was given to black pepper, it resulted in an increase in the number of leaves and branches, nodes, fruits, and fruit branch length.

AMF develops symbiotically and mutualistically with plants. Both nodulation and phosphorus absorption are aided. After nitrogen, phosphorus is a key macronutrient for plants, contributing to both plant development and metabolism. It colonizes the plant root and facilitates the host plant's soil phosphorus and water uptake. AMF enhances soil composition and aids in plant development and nutrient absorption when applied with compost. Glomus microagregatum, Funneliformis geosporum, Claroideo glomus etunicatum, Funneliformis mosseae, Rhizophagus intraradices, and Glomus claroideum are a few AMF species that are utilized as an inoculant for biofertilizer. In comparison to using them separately, AMF boosts the parameters of plant development more than composted rock phosphorus-fed dung does. The chlo-rophyll and carotenoid content of agricultural plants is likewise increased by AMF. It aids plants in absorbing nitrogen in addition to phosphorus. AMF and composted rock phosphorus-fed dung treatments increase soil's organic matter by 1.42%.

The mung bean plant's shoot biomass and root biomass are increased by the combination of AMF and composted rock phosphorus fed manure. Nitrogen absorption is 58.38 mg/plant and phosphorus uptake is 4.61 mg/plant with this combination. In addition to AMF, there are other bacteria and fungi that can fix phosphorus in the soil. These organisms, either alone or in combination, fix phosphorus for the plants when given to the soil. Appropriate substrate selection is critical for AMF mass production. The best substrate for the growth of AMF is soil containing composted rice straw. Because it includes polysaccharides, lignin, silica, nitrogen, cellulose, and K, Ca, P, Fe, Mg, Na, and Mn, rice straw is the most ideal material. It needs a host to multiply, and Sorghum bicolor and Triticum aestivum are the most acceptable hosts for Glomus mosseae. AMF multiplication is governed by the host-substrate pair. For its large-scale production to be employed as biofertilizer, this selection is crucial [4], [5].

Thuringian Bacteria

It is a gram positive, aerobic, or facultative spore-forming soil bacteria. This organism's insecticidal qualities are what make it most well-known. However, it is also present as an endophyte in rice, cotton, soybeans, and cabbage. Plants, both legume and non-legume, may have it penetrate their roots. It promotes plant growth and nodule development. Plant infections are decreased. By creating the growth hormone indole-3-acetic acid, it may aid in plant development. Additionally, it may create siderophores, phosphate solubilizing enzyme, and 1-aminocyclopropane-1-carboxylate-deaminase. By generating IAA, Bt strain C25, which was obtained from a cabbage plant, promotes Lactuca sativa development. Rhizobium leguminosarum PR1 and the growth hormone-producing Bt strain KR1 are given to pea and lentil plants to promote growth. This strain encourages soybean development by increasing shoot weight, nodule formation, root weight, root volume, and total biomass when combined with Bradyrhizobium japonicum-SB1. By promoting root development, the Bt strain that generates ACC deaminase encourages plant growth. Arbuscular mycorrhizal fungus and the Bt strain enable plants endure stressful conditions. One of the characteristics of Bacillus species is the presence of siderophores. It binds iron, which causes plant pathogens to die from an iron shortage. Another distinguishing trait of the Bacillus species is its capacity for phosphate solubilization.

Microalgae

Microscopic photosynthetic creatures are called microalgae. Both freshwater ecosystems and marine ecosystems include them. It may substitute chemical fertilizer since it promotes plant development and can boost agricultural productivity. Additionally, it aids in CO2 absorption, which lowers the amount of carbon dioxide released into the atmosphere. Because it enriches the soil with organic materials, it helps strengthen the soil's structure. Microalgae produce extracellular polymeric compounds and are rich in metabolites. Additionally, it aids in minimizing soil nitrogen loss. Brewery waste may be transformed by microalgae into an organic form that can be used as a biofertilizer. Municipal solid waste may also be converted and degraded. Chlorella sp. and two other microalgae thrive on this solid waste. Likewise Scenedesmus sp. Because these microalgae contain more nitrogen and phosphorus, they may therefore be utilized as biofertilizer to grow plants more successfully. Green algae called Chlorella sorokiniana may be found in soil. Within 12 days of incubation, it might enter the exponential growth phase because to its rapid growth rate. Because it has a high nutritional content, the filtrate from Chlorella sorokiniana may be utilized to sprout wheat seeds more quickly than a control. These microalgae's filtrate may increase plant biomass and stem length. Both Spirulina plat-ensis and Chlorella vulgaris are significant biofertilizers because they provide vital amino acids, fatty acids, proteins, and carbohydrates[6].

By causing the insoluble potassium minerals mica and feldspar to dissolve, these bacteria may also solubilize potassium. These organisms reduce the pH of the soil, or secrete acid, to solubilize phosphate and potassium. A pH reduction of 3.2 to 4.0 units is possible. In the soil, they do phosphatase activity. Indole may also be produced by them. When evaluated as a biofertilizer on potatoes, these bacteria respond well. The output of potato tubers was quadrupled by these biofertilizers. Additionally, it increases potato root length, the number of roots, and the number of lateral shoots on the plant. When combined with phosphorus fertilizer, Bacillus subtilis performed better than when used alone. In the case of wheat, it boosts plant height by 8% and branch count by 1.74%. Additionally, fungi can efficiently solubilize phosphate and boost crop output and expansion. Penicillium, Talaromyces, and Aspergillus spp. are significant fungi that solubilize phosphate. Talaromyces pinophilus and Penicillium oxalicum are more powerful than Aspergillus niger. Since fungus create high amounts of acid, they are better at solubilizing phosphate than bacteria. Another potential phosphate solubilizing fungus, Trichoderma, is 141% effective in fixing phosphorus. Because it demonstrated a 39% growth boost in soybeans, it may serve as a biofertilizer for those plants. Trichoderma is one of the greatest biofertilizers for encouraging plant development and boosting soil fertility when combined with an organic carrier like rice bran and compost. The best combination for tomato plant development is rice bran and compost in a 1:3 ratio.

Azotobacter

It is well recognized for its ability to fix nitrogen and is a very effective bio-fertilizer for cereal crops. Additionally, it secretes vitamins, antifungal agents, and growth hormones. Additionally, it can create sid-erophores and fix phosphorus. It also enriches the soil with ammonia. You may spread it on the soil using a carrier or liquid inoculants. Carrier inoculants have certain drawbacks, including the potential to make biofertilizer less effective and more expensive. As a result, liquid inoculants that include nutrients for the support of the bacteria employed in biofertilizer are becoming more common. Azotobacter increases the dry matter of plants when treated using a carrier at a rate of 20 g/kg seed and liquid inoculants at a rate of 4.0 ml/kg seed. The product's microbe concentration is maintained at >109 cells/g of carrier or /ml of liquid inoculants. Azotobacter and phosphate-solubilizing bacteria work well together to increase maize and strawberry yields. Because it produces growth regulators like auxins and gibberellins, azotobacter also improves soil nutrient uptake. Comparatively to carrier inoculants, liquid inoculants boost the microbial population in the soil. When applied to the soil, azotobacter and phosphate-solubilizing bacteria exhibit dehydrogenase activity.

Enzymes called dehydrogenases aid in the oxidation of soil organic materials. Liquid inoculants are used in this activity more so than carrier inoculants. Sugarcane responds more favorably to the addition of azotobacter and phosphate-solubilizing bacteria, farmyard manure, and the required fertilizer dosage based on soil testing. In low phosphate soil, it may also aid in the growth of cane. These processes not only provide plants essential elements for development, but they also enrich the soil with nutrients, making it productive after crops have been harvested. Additionally, it raises the nutritional value, leaf content, and maize yield. A brasilence in addition to A. When lipoferum is inoculated in maize, more nutrients are present in the leaves and grains. It is a category of rod-shaped, gram-positive, aerobic or facultatively anaerobic bacteria that produce endospores. Extreme environmental conditions are not a barrier to the growth of these microorganisms.

Biofertilizer production: To prepare biofertilizer, chicken manure is used as a nitrogen source in low doses of 100 g and high doses of 200 g; eucalyptus leaf litter is used as a carbon source in low doses of 300 g and high doses of 500 g; and rhizospheric soil is used as a micronutrient source in low doses of 50 g and high doses of 100 g. These organic substrates are sieved, crushed, and dried before being dried, crushed, and sieved. A consortia of azotobacter and azospirillum was introduced while maintaining a moisture content of up to 32%. The outcome of combining an organic substrate with a microbe was left to stand for 60 days in order to produce biofertilizer. After measuring the pH, carbon and nitrogen contents, it was discovered that the pH declines with time intervals of 0, 30, and 60 days.

Characteristics: The PGPR consists of the bacteria Rhizobium, Bradyrhizobium, Streptomyces, Bacillus, and Azotobacter. These are the bacteria that aid in enhancing growth and are found in the rhizosphere of the plant. The symbiotic relationship between these bacteria may improve the growth of certain grains and leguminous plants. The soybean plant's root nodules contain bradyrhizobium, which aids in fixing nitrogen for the plant. Streptomyces play a crucial role in bioprotection. By shielding the plant from illnesses, they aid in its survival. Important substances including vitamins, alkaloid, plant growth factors, enzymes, and enzyme inhibitors may be produced by it.

Results: Under N deficient conditions, biofertilizer was shown to be more effective than control at promoting shoot and root development in mung bean, cowpea, and soybean. Biofertilizer boosts the shoot and root development of mung bean, cowpea, and soybean in comparison to the control when nitrogen is added. This biofertilizer was discovered to be effective in fixing nitrogen and forming nodules. S. griseoflavus P4 and B. yuanmingense promote soybean nodule development. Additionally, it effectively increases the biomass of the shoots of mung beans and soybeans when compared to control. In the case of cowpea, it only raises shoot biomass in the early phases of development. The addition of biofertilizer also increases the absorption of phosphorus and nitrogen. Mung bean and soybean nodule development increases throughout the full bloom and early-pod fill stages. In terms of nitrogen intake, it is higher in the stages of mung bean and soybean that have three unfolded trifoliate leaves, full bloom, and early pod fill. However, in the case of cowpea, N absorption is greater at the stage of unfolded three trifoliate leaves. In the case of soybeans, phosphorus uptake occurs at all phases. For cowpea, the stage with three unfolded trifoliate leaves is when phosphorus absorption is greatest. Mung bean, cowpea, and soybean biofertilizer may help enhance the quantity of pods per pot. Because of this, the use of a mix of bacteria as a biofertilizer is particularly successful in promoting plant growth. A variety of streptomyces species. MBR-52 promotes a plant's adventitious root system[7].

The drawbacks of biofertilizers

The adoption of biofertilizer is one of the main issues it faces. One assessment on the usage of biofertilizers among farmers in Indonesia revealed that factors including age, education, and farming experience have an impact on whether biofertilizers are accepted for use. The results of the same poll indicated that farmers in their prime years are more receptive. The degree of education of farmers is also crucial to the approval process. Compared to farmers with less education, those with greater education can more readily absorb any new technology. This is so that people may embrace new ideas and develop the vision necessary to see and comprehend changes in the world. The reaction of biofertilizer is a significant issue as well. Because microorganisms make up biofertilizers, their effectiveness is reliant on the environment. Water is the most crucial component for the survival of all organisms. So, the main barrier restricting the response effectiveness of biofertilizer is a lack of water. Due to the lack of observable plant development and production, the use of biofertilizer is prohibited in dry and semiarid regions.

The vitality and efficacy instability of biofertilizer is another drawback. Its use was hence confined among farmers. Plasma-based approaches were created to address this issue. Farmers often utilize plasma since it is a novel approach that helps to boost its vitality and effectiveness. Other drawbacks of biofertilizers are their short shelf life, lack of usable bacterial strains, and need for high doses to cover a big area. If delayed release fertilizer technology is employed, this high dosage issue may be lessened. The slow-release fertilizer known as urea-formaldehyde encapsulation was created utilizing polymeric matrix and biofertilizer.

Achievement of Biofertilizer

One of the benefits of utilizing biofertilizer is that it boosts agricultural plant productivity more than chemical fertilizers do. A study on soybean farming in Indonesia revealed that using biofertilizer in addition to liquid and organic fertilizer boosts soybean farming's productivity and profitability. Additionally, biofertilizers help plants adapt to stressful situations. Examples include the following: When given to cucumber seedlings, Pseudomonas aeruginosa PW09, an endophyte, helps it combat both Sclerotium rolfsii stress and NaCl stress. Micro Dielectric Barrier Discharge plasma was a technology created and utilized to overcome one of the biofertilizer's limitations the instability of vitality and efficiency. This method was used on the Bacillus subtilis CB-R05 strain.

This is a novel method that makes use of plasma, or ionized gas. It may either activate or deactivate biological substances depending on how it is used. High voltage burst pulses were used in this method to create plasma. Altering the duty ratio of burst pulses may change the plasma's energy. N2 plasma and air plasma are the two forms of plasma. The effectiveness and quantity of bacteria increased as a result of this therapy. When employed in rice crops, bacteria treated with plasma demonstrated greater growth and yield, resistance to fungal infections, higher levels of IAA and salicyclic acid, improved vitality, colonization, phytohormone level, and disease tolerance. Oleamide, cyclohexanone, and phosphoric acid levels dramatically increased in plasma-treated bacteria, but succinic acid, glycerol, oleanitrile, and stearic acid levels significantly decreased.

On the surface of biotic or abiotic materials, microbes may form biofilms. Water and nutrients are provided by these biofilms. Consequently, biofilms sustain bacteria more effectively than planktonic forms, making biofertilizer in the form of biofilms more effective and yielding superior results. On greenhouse tomatoes, Bacillus and Pseudomonas species work best when utilized as biofilms. When used as a biofilm, Pseudomonas species may boost several growth metrics, such as height and root dry weight. Similar results for tomato root length may be obtained from Bacillus species. It demonstrates that if this procedure can be optimized, it may be a superior choice.

Associated with Biofertilizer

Biofertilizer has proven to be one of humanity's most beneficial discoveries since it aids in preserving the environment's viability. But every good item also has a negative side effect. The development of antibiotic resistance genes in aquatic eco-system bacteria is one of these effects of biofertilizer. Animal excrement is biologically treated to create biofertilizers, which horizontally transmit plasmid-based resistance genes to microorganisms. Vibrio parahaemolyticus acquired fluoroquinolone resistance as a result of the use of biofertilizer in an aquatic setting. As a result, the seafood is dangerous for human health and unfit for ingestion. In order to prevent this factor from becoming the next agent that restricts the use of biofertilizer, regulation of these resistant genes must be taken into account.

New Strategy

Prawn and crab shells may be used as a novel method for producing biofertilizers. Chitin, protein, and inorganic substances like calcium carbonate are all abundant in them. Making biofertilizer from crab shells makes it environmentally friendly. The waste product of the production of sea crab meat is crab shell. Chitin and chitosan, which are found in crab shell, aid in promoting plant development. Crab shell biofertilizers may be used to aquatic ecosystems. By using crab shell biofertilizer, watercress shown increased shoot length, root development, and wet weight. A novel method to enhance the current biofertilizer is to combine nanobiotechnology with fertilizer. In order to create innovative nano-biofertilizer, nanomaterial and biofertilizer were combined. Due to the nanomaterial's coating, this combination benefits from increased soil moisture absorption and microbial life. An improved kind of bio-fertilizer known as nano-biofertilizer promotes more effective and efficient sustainable agricultural growth. It is created by reducing biofertilizer to a nanosize with the help of a covering made of nanomaterials. Eco-friendly, renewability, cost-effective, less time in manufacturing, needed in smaller quantities, and improved nutrient usage efficiency are some of the characteristics it offers.

The nutrients are released slowly as a result of the coating of nanomaterial, making them accessible to the plants for a longer period of time. It might overcome the drawback of biofertilizer and improve it as a product for long-term growth and development. Because bacteria that encourage plant growth and nutrient uptake are coated within nanomaterial during its synthesis, it overcomes the problems of shelf life, poor efficiency, high cost, and non-renewability. Chitosan, zeolite, and polymer are examples of nanomaterials used for coating. Because it promotes nutrient absorption and distribution in plants and accumulates components necessary for photosynthesis, nano-biofertilizer may boost plant production. Crop plants respond extremely well to biofertilizer that has been coated with gold or silver nanoparticles. According to a research from Iran, Biozar® nano-biofertilizer boosted wheat crop growth, seed yield, and yield components. Another Iranian research discovered that using nano-Zn and biofertilizer together boosts Zea mays grain production. One research from Ludhiana found that sugar beet plants had increased leaf area, root biomass, net photosynthetic productivity, and sucrose content of 1.03%[8].

To find a more effective and acceptable method for agricultural development, more similar combinations should be tested in the future, along with organic fertilizer. It was discovered that coinoculating bacteria produces superior outcomes than applying them separately. Therefore, more of these mixtures need to be tested in the near future to produce a more effective product and prevent the degradation of our environment. In addition to employing rhizobacteria as a biofertilizer, finding rhizofungus is also necessary for the unstoppable expansion of agriculture since fungi may assist plants in overcoming difficult environmental conditions. Along with rhizobacteria, phyllobacteria may be helpful in finding solutions to a variety of issues pertaining to agricultural niches. The search for and improvement of phyllosphere microorganisms need extensive study. The environment has an impact on the metabolites that microorganisms produce, making them sometimes less effective in field circumstances. Bioinformatics and genome sequencing are required to make this situation better. Biosynthetic and action potential may be boosted by genome mining and genetic engineering. Therefore, future study in this area should focus on creating more effective and very promising biofertilizers.

A powerful technique for lowering pollutant pressure and promoting environmentally sustainable development is biofertilizer. It either directly or indirectly aids in plant development. The right pH, temperature, carrier molecule, etc., are needed to prepare biofertilizer. The best conditions for biofertilizer are 6-7 pH, 30–40°C temperature, and peat as the carrier molecule. The plant and the soil are given extra assistance when chemical fertilizers are combined with biofertilizers. Because they provide more nutrients and organic matter to the soil, these combinations offer better reaction and output in terms of preserving soil fertility and increasing plant production. It is crucial to apply biofertilizer in the right quantities, mixes, and intervals for the crop plant to respond more effectively. This knowledge of biofertilizer is crucial for its more advantageous outcomes. In addition to bacteria, fungi, mixtures of fungi, and bacteria and fungi, are also crucial for promoting plant development, enriching the soil with nutrients, raising its fertility, and preserving the native microbial community.

CONCLUSION

In order to maintain soil structure and integrity as well as increase crop production and growth, it is necessary to locate and search for ever-larger populations of naturally occurring, innate microbes. The sort of biofertilizer to be used depends greatly on the nature and texture of the soil. Before selecting a biofertilizer, it is crucial to understand the kind of soil. Because microbes can only function under specified pH, temperature, and other development parameters, the acidity or alkalinity of the soil will dictate which microbe should be employed to produce biofertilizer. Therefore, biofertilizer optimization is crucial for maximizing its benefits. Metal pollution is rising daily as a result of the formation of more and more enterprises nowadays. These harmful heavy metals prevent plants from growing by obstructing their growth systems. Heavy metal tolerant biofertilizers aid plants in surviving these circumstances. Therefore, it is crucial to look for more and more metal-tolerant bacteria that may function as microbes that encourage plant development. The limits of biofertilizers may be overcome in a number of ways, including by employing SAP, urea-formaldehyde encapsulation, biochar, and nano-biofertilizer. The potential of nano-biofertilizer, a novel and developing technology, to improve outcomes in sustainable development, has not yet been fully investigated. There haven't been many research done in this area. Future attention should also be directed more on the creation and improvement of ever more nano-biofertilizers. The solution to that issue should likewise be designed while keeping its negative impacts in mind. Similar to how combining biofertilizers with other biofertilizers, green manure, and chemical fertilizer boosts their effectiveness, combining all of these with nano-biotechnology might result in more promising eco-friendly agricultural products.

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CHAPTER 16

FABRICATION APPROACHES FOR BIOFERTILIZERS

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ABSTRACT:

A very significant source of nutrient delivery for plants is the use of biofertilizers as a potential alternative to chemical fertilizers. Biofertilizers have the potential for larger agricultural uses and are inexpensive and environmentally benign. This is because using biofertilizers may boost plant growth and production while also removing negative health and environmental effects associated with chemical fertilizers and providing additional protection against a variety of plant diseases. In-depth knowledge about biofertilizers and the numerous methods for making them is provided in this book chapter. There is extensive coverage of the various biofertilizer kinds and their related functions. There is a lot of discussion on the different inoculant carriers for biofertilizer formulation, carrier forms, and the many ways that biofertilizers are applied. Also addressed are the difficulties and constraints that impact the use of biofertilizers. In order to attain greener, cleaner, and more sustainable food production, the chapter concludes with some suggestions and future possibilities for biofertilizer development, preparation, and application.

KEYWORDS:

Biofertilizers, Nutrients, Inoculant, Bacteria, Solubilization, Carrier, Formulation, Nitrogen Fixation.

INTRODUCTION

The quality of the soil affects both production output and the quality of agricultural yields. Poor soil quality is mostly caused by drought, salinization, and continuous use of agricultural land without sufficient nutrient replacement. It is important to maintain the soil quality since, in general, inadequate topsoil management often results in decreased crop output. Chemical fertilizer application is the most popular and commonly used method for preserving soil quality and assuring sufficient nitrogen availability to the soil for higher crop yields. Sustainable agriculture is increasingly emphasizing the use of biofertilizers as a viable alternative to synthetic/chemical fertilizers. This is because using chemical fertilizers in agriculture poses harmful health and environmental risks, including air and water pollution, soil degradation, the greenhouse effect, and the need for environmentally friendly and economically viable solutions for the production of food that can satisfy the demands of our expanding human population. Regardless of the volume of output, biofertilizers are organic, eco-friendly, economical, and practical alternatives for agricultural operations. In addition to adding nutrients to the soil, these biofertilizers support farmlands' biodiversity and soil structure maintenance. In order to increase the amount of nutrients in the soil, biofertilizers primarily fix nitrogen, solubilize phosphorus, and create compounds that encourage plant development[1].

Microbiological inoculants and biofertilizers are compounds created to provide plants' nutritional requirements via microbiological processes. When used on soil, seeds, or plants, these compounds include live microbes that encourage plant development. Biofertilizers are essentially carrier-based microbial formulations that include advantageous microorganisms in a viable condition that promote nutrient availability and boost plant development. Commonly used microbial inoculants include rhizobacteria that promote plant growth, nitrogen, and phosphorus. Biofertilizers are mixtures made up of different types of microbes, organic materials, and dead plant tissues that nourish the soil and plants with the necessary nutrients. By improving soil fertility via the use of biofertilizers, crop output is increased. Biofertilizers are able to transform nutrients that were previously inaccessible into forms that are available to plants and used by them by expanding the microbial population of the rhizosphere. Microbial populations control the amount of soluble nutrients available in the soil for plant absorption.

The usage of biofertilizers may result in the following advantages:

a. Enhanced agricultural output and plant development as a result of improved soil fertility.
b. Lessening of environmental contamination brought on by the manufacture and use of chemical fertilizers.
c. Defense of plants against numerous diseases found in the soil.
d. Economic appeal and cost-effectiveness.
e. An increase in the fertility, condition, and general health of the soil.

Utilizing biofertilizers improves the microbial activities, increasing the amount of nutrients accessible to plants. By fixing nitrogen in the atmosphere, solubilizing insoluble phosphates, and creating chemicals that encourage plant development in the soil, biofertilizers assist to increase the fertility of soils. The continual use of biofertilizers increases soil fertility and is both economical and environmentally benign.

Biofertilizer Types

The following kinds of biofertilizers will be covered: blue-green algae, phosphate-solubilizing biofertilizers, phosphate-mobilizing biofertilizers, nitrogen-fixing biofertilizers, and biofertilizers that encourage plant development.

Biofertilizers that Fix Nitrogen

The development and production of plants depend on nitrogen. It is widely accessible and abounds in the air. However, plants are unable to use atmospheric nitrogen. The nitrogen must be changed into a form that plants can utilize before it can be used by plants. This is accomplished by turning atmospheric nitrogen into ammonia, which plants can readily access. Biological nitrogen fixing is the term for this transformation. Through the use of a catalytic enzyme, nitrogen-fixing microorganisms convert atmospheric nitrogen into ammonia during the BNF process. Rhizobium, Azospirillum, Azotobacter, Bradyrhizobium, and other well-known examples of nitrogen-fixing microorganisms. These microbes may also be divided into free-living, symbiotic, and asymbiotic/associative types[2].

Rhizobium

The Rhizobiaceae family includes Rhizobium. They take the shape of root nodules in plants and are symbiotic in nature. Rhizobium may symbiotically grow alongside non-leguminous plants and legumes to fix atmospheric nitrogen. Rhizobium can only fix 50–100 kg of nitrogen per hectare using legumes. Rhizobium invades the root hairs of legumes, multiplies there, and settles down to create root nodules, which resemble tumors and are where ammonia is produced. Various legumes need various kinds of rhizobium to successfully nodulate. Therefore, the extent of effective nodule formation by rhizobium depends on the availability of a suitable strain for a certain legume.Different rhizobial strains may influence different types of legumes, but an enhancement in growth only happens when nodules are generated by efficient rhizobial strains. The matching of microsymbionts is thus crucial for maximizing nitrogen fixation and should be done with great care. Furthermore, the presence of leguminous crops in the field affects the population of rhizobium in the soil. Therefore, when the availability of the legumes declines, so does the rhizobium population. Associative symbiosis describes the relationship between Azospirillum and various plants, notably those with the C4 dicarboxylic route of photosynthesis. This is as a result of

Azotobacter is a member of the family Azotobacteriaceae. They are aerobic, photoautotrophic, free-living, non-symbiotic bacteria that are mostly found in neutral and alkaline soils. Azotobacter chroococcum is the bacterium that is most often discovered in arable soils. Azotobacter beijerinckii, Azotobacter insignis, Azotobacter macro-cytogenes, and Azotobacter vinelandii are some of the other species of this bacterium. Vitamin B complex, phytohormones such naphthalene acetic acid and gibberellins, and other chemicals produced by Azotobacter enhance plant development and mineral intake while inhibiting the growth of certain root diseases. On the roots of the Paspslum notatum plant, Azotobacter has been shown to fix nitrogen at a rate of 15–93 kg/ha. The mortality rate of seedlings is claimed to have significantly decreased as a consequence of the Azotobacter indicum strain's ability to generate a range of antifungal antibiotics that may stop different fungus infections from developing in the root area[3].

Biofertilizers that Solubilize Phosphorus

Phosphorus, which makes up around 0.2% of a plant's dry weight, is a crucial ingredient for plant growth and development. The soil contains significant levels of phosphorus. However, the majority of it is there in forms that plants cannot use. Phosphorus is thus considered to be the second important nutrient that limits plant growth after nitrogen. Because phosphate rock minerals are often quite insoluble, it might be challenging to provide enough phosphorus for plant absorption.

Biofertilizer that Moves Phosphate

Popular and significant phosphorus mobilizers are mycorrhizae. By making soluble phosphorus available to plant roots, phosphorus mobilizers make it easier for roots to obtain phosphorus that would otherwise be unavailable to them. Mycorrhizae are a term used to describe a symbiotic relationship between fungus and plant roots. Both sides are able to satisfy their nutritional demands because to this symbiosis. Fungi are found in the roots of many Gymnosperms, Angiosperms, Thallophytes, and Pteridophytes and are omnipresent in nature. The fungus provide the host plant with the necessary nutrients, water, hormones, and defense against root infections by obtaining carbohydrates from the pho-tosynthates of the host plant. Phosphorus mobilizers are important for boosting plant growth and nutrient absorption. Thanks to the fungi's delicate absorbing hyphae, this nutrient intake is made possible. The host plant is protected from biotic and abiotic stressors by the fungal endophyte, which may also promote growth and boost reproduction. According to studies, plants with mycorrhizae are more resilient to stressors such those brought on by plant transplantation, soil salinity, high soil temperatures, and toxicity from heavy metals.

Commonly recognized as the most prevalent fungus in agricultural soils, arbuscular mycorrhizae fungi make about 5% to 50% of the biomass of soil microorganisms. Seven genera of fungi Acaulospora, Gigaspora, Entrophospora, Glomus, Gigaspora, Archaeospora, Scutellospora, and Paraglomus produce Arbuscular mycorrhizal symbiosis with plants. The AM fungus also help plants use water more efficiently. They work together to increase the hydraulic conductivity of plant roots in lower-water parts of the soil, which helps the plants absorb more water. There have been several suggested methods through which AM fungi may assist in facilitating the activation of plant defense mechanisms. Increased cell wall lignification, changes to mycorrhizosphere exudation patterns, and competition for colonization and infection sites are a few of these changes.

Biofertilizer with Potassium

One prominent type of biofertilizers that greatly contributes to the growth and development of plants is the potassium biofertilizers. After being modified chemically or biologically, waste materials like mica may be used to create potassium biofertilizers. The unusable potassium in the waste mica may be transformed into plant-accessible forms using the composting approach. This is a result of the acidic environment created when the used mica was composted. However, certain rhizobacteria may create potassium in the soil in an easily assimilated form. For instance, silicate bacteria have been reported to be able to dissolve the insoluble minerals potassium, silicon, and aluminum. It has been observed that Bacillus, Aspergillus, and Clostridium bacteria are excellent choices for potassium solubilization in various crops [4]. Potassium aids in the transfer of sugars and starches as well as the activation of enzymes. Additionally, it facilitates the absorption of nitrogen, encourages photosynthesis, and keeps the cell's turgor pressure stable. Protein synthesis depends on potassium. Higher disease resistance, which improves stress tolerance and crop quality, are some additional advantages of potassium. Externally applied potassium fertilizers are often used to provide potassium to the soil.

Biofertilizers that Promote Growth

These are biofertilizers having the ability to promote plant development. They are a particular subgroup of rhizobacteria that are naturally present in soil close to plant roots, where they develop special symbiotic connections with plants to help with nutrient availability and plant safety. These bacterial groups include the vast majority of phosphorus-solubilizing and nitrogen-fixing bacteria, which may operate as biofertilizers and boost plant development by producing compounds that stimulate growth. Important macro- and micronutrients including nitrogen, phosphorus, potassium, iron, and copper are all made available by these rhizobacteria. Additionally, they aid in promoting the development of other advantageous bacteria and fungi. There are two basic ways they might encourage plant growth: directly or indirectly. The direct strategy involves increasing nutrient accessibility or altering plant hormones. The indirect approach involves lessening plant growth inhibition caused by pathogens.

Rhizobacteria that promote plant development have a variety of advantageous impacts on plants, including greater seed germination, increased chlorophyll content, and improved nodule formation in legumes. They also provide protection to plants against several abiotic and biotic challenges, including the capacity to fight off the invasion of numerous diseases, in addition to creating favorable circumstances for the absorption of nutrients. Some of the well-known plant growth-promoting rhizobacteria include Azotobacter, Arthrobacter, Bacillus, Alcaligenes, Azospirillum, Pseudomonas, Burkholderia, Serratia, Klebsiella, and Enterobacter. These organisms aid in soil enrichment by breaking down complicated materials into useable forms. Additional categories for these PGPR include bio-stimulants, biofertlizers, and bio-protectants.

Green and Blue Algae

These are free-living, nitrogen-fixing microorganisms also referred to as cyanobacteria. There are eight separate families among them, and they are phototrophic. There are species of colonial and unicellular cyanobacteria. For field applications, cyanobacteria including Anabaena, Aulosira, Cylindrospermum, Nostoc, Plectonema, Scytonema, and Tolypothrix are often employed. In addition to nicotinic acid, folic acid, pantothenic acid, amino acids, IAA, sug-ars, and polysaccharides, BGA also produces other growth-promoting compounds. The agro-climatic conditions affect BGA's capacity to fix nitrogen. Using BGA, nitrogen fixation rates of 25% to 30% N/ha/season have been recorded in rice fields. BGA feeds the soil with a number of secondary metabolites, hormones, and extracellular carbohydrates in addition to fixing nitrogen in the soil. BGA aid in enhancing the soil's structure and health. Additionally, they improve the soil's ability to retain water and hold it, and they help to restore some of the nutrients to salt-affected and chemical fertilizer-degraded soils[5].

Methods for Making Biofertilizers

Formulation of the Vaccine

While the living microbial cells are still alive, biofertilizers are often created such that they may still promote soil fertility, plant development, and production. The creation of biofertilizers is essentially a multi-stage procedure that combines several strains with certain chemicals to protect the cells during storage. The viability of microbial inoculant as a biofertilizer is highly dependent on the formulation technique utilized in its creation. Essentially, the preparation method entails incorporating live microbial cells into a suitable carrier along with chemicals that stabilize and safeguard the inoculants throughout transit, storage, and application. It is crucial that the formulation be made in a way that makes handling and application simple. By shielding the bacteria from severe external variables and preserving the soil's microbial activity, this will assure successful transportation of the formulation to the target.

The microbial strain and the process used to prepare the inoculant are the two key determinants of successful biofertilizer formulations. In most cases, the formulation strategy used will determine whether an inoculant is successful. Studies have demonstrated that when introduced to the target plants, highly effective biofertilizer forms significantly improve their activity. However, since most strains originating from the same bacterial species have comparable physiological characteristics, the optimization of an inoculant is often not reliant on the microbial strain utilized. Therefore, a method created utilizing one strain of a species may be simply modified for use with another strain. A good formulation should have the following desirable characteristics: the ability to add nutrients; the use of readily available, inexpensive raw materials; environmental friendliness; pH adjustment; flexible and gradual release of bacteria into the soil; ease of application that is compatible with standard seedling equipment; stability and extended shelf life under adverse conditions.

Carriers for Making Biofertilizer

The delivery vehicles used to transport the manufactured micro-bial inoculants from commercial fermenters to the field's rhizosphere are known as carriers. They are crucial in making sure the needed cell population is delivered in a viable form. These carriers provide the earth a temporary protected habitat for the bio-fertilizers. This defense may take the form of a protected pore space surface or it may take the form of nutritional defense in the form of a suitable substrate. The carriers may be created using synthetic, organic, or inorganic materials. High water retention ability, bacterial growth and survival, affordability and availability in powder and granular form, a pH that is nearly neutral or easily adjustable, the ability to add nutrients, ease of handling during mixing, curing, and packaging operations, the absence of heat wetting, almost sterility or ease of sterilization, chemical and physical uniformity, and good adhesion to seeds are all qualities that a good carrier should possess. It should not be poisonous to the inoculated biofertilizers, pollute the environment, be difficult to biodegrade, acceptable for all rhizobia, and free of lump-forming substances. However, it is rare to find a single carrier with all these qualities that may serve as a universal carrier for all biofertilizers. However, a good carrier ought to possess the majority of these traits[6].

Sterile Transporters

Inoculants made using sterilized carriers have a longer shelf life and promote more microbial growth. Furthermore, the use of pre-sterilized carriers offers a substitute for prolonging culture preparations by diluting the broth without compromising the final quality of the inoculant and removes or significantly minimizes the presence of contaminants. However, there are a few disadvantages to using sterile carriers. The cost of manufacturing will go up, a sterilizing machine will need to be installed with the necessary capacity to satisfy production needs, manpower costs will go up, and aseptic procedures will need to be followed when the culture is added to the pre-sterilized carrier package. It may be difficult to identify which of these parcels has been infected, since several of these packages could be. While these restrictions may not be significant or overtly visible for small-scale processes, they provide significant difficulties for large-scale manufacturing.

Transport Form

The carrier shape mostly depends on the application mode that will be employed. It also depends on the cost and the planting tools that will be employed. Granules, beads, or powder forms, as well as liquid forms, are the most common carrier types employed. Powdered inoculants are often used to apply to seeds before to planting. Inoculant carriers may be employed in seed coating in powdered form. It may also be dissolved in a liquid to create a slurry, which may then be spread over the ground. As an alternative, the seeds or plants might be coated before planting by being dipped in the slurry. On the other hand, it has been suggested as a criterion that 50% of the particle size should pass through a 0.075-mm mesh screen for powder materials with particle sizes that can pass through a 0.25-mm sieve. Finer particle size has been used to improve seed adherence. Granular inoculant may be sown along with the seed straight into the ground.

Granular particles with diameters between 0.35 and 1.18 mm provide easy absorption, curing, and uniform flow for the culture. For application rates of 5 to 30 kg/ha, depending on the width of the row, the granular form offers much more rhizobia during application than the seed application technique does. The total amount of inoculant delivered by the seed application technique is just 210 g/ha. Granular inoculant has a significant financial disadvantage because to its high cost. However, it produces superior outcomes when used in a variety of situations, particularly after planting and in environments with environmental challenges. It also significantly increases plant nodulation. Based on the kind of carrier utilized, which makes up a bigger portion of the inoculant and offers food and protection to the microorganisms from environmental challenges from the formulation through application, the different types of biofertilizer formulations may be categorized [7].

Bio formulation Using Solid-Based Carriers

The first biofertilizer formulations were created only using solid-based carriers. Inoculants made using solid carriers are referred to as solid-based carriers. This procedure involves mixing the inoculum with a solid carrier consisting of an inert substance that acts as a means of delivering the bacteria from the lab to the field. There are several instances of solid carriers that have been used as inoculant carriers. Peat, perlite, mineral soil, charcoal, inorganic clay, zeolite, talc, vermiculite, sand, and plant byproducts are some of them. The following general categories may be used to further categorize these solid carriers:

a. Soils, including peat, coal, coal with additions, clays, and inorganic soils.
b. Materials made from plant waste, such as compost made from bagasse, rice husk, farmyard manure, sawdust, corncobs, coir dust, cellulose, etc.
c. Materials that are inert, such as calcium sulphate, perlite, powdered rock phosphate, poly-acrylamide gel, and alginate beads that have been encapsulated.
d. Oil-dried bacteria or lyophilized microbial cultures that are then added to a solid carrier.

Only peat, the most popular solid carrier for the creation of biofertilizers, will be covered, however.

Formulations by Peat

Peat is by far the most used carrier since it is reliable and has a history of successful uses. Peat is fundamentally a complicated and ill-defined substance made up of several sources, each of which has a particular ability to assist cell development and survival. Plant components that have partly decomposed and accumulated over time make up peat mixtures. When peat is employed as a carrier, it offers a nutrient-rich, protective environment that promotes the development of a variety of microorganisms with the capacity to establish microcolonies on particle surfaces and in crevices. Peat has several advantageous qualities, including a large surface area that promotes the growth of the inoculant, a high water-retentive capacity, simplicity of usage, and universal acceptance. However, some of its drawbacks include lesser bacterial resistance to physical stress during storage, inconsistent quality, high cost, and unavailability in certain regions.

Formulation of Liquid Immunizations

These are essentially goods with an aqueous, oil, or polymer basis. In addition to the necessary microbes and nutrients, liquid formulations also include unique cell protectants and additives that help the cells survive both during storage and after being applied to seeds or soil. Liquid inoculants are made up of a medium that fosters the development of microorganisms and other additives that protect cells, as well as carbon, nitrogen, and vitamins. These additional additives aid in product stabilization, protection of the inoculant from environmental stresses when applied to seeds and soil, improvement of seed adhesion, aid in binding or inactivating soluble toxins coated on seeds, prevention of osmolysis, and improvement of rhizobia survival during storage. In addition to preserving the high microbial populations, the inclusion of cell protectants in liquid inoculum aids in the creation of resting cells that provide better resilience to abiotic stressors, which ultimately results in increased survival rates for the bacteria. It has been noted that the kind and quantity of additives may influence how well an inoculum works.

The choice of an addition should be made based on its capacity to preserve bacterial cells during storage as well as when applied to seeds exposed to different detrimental environmental stressors, such as high temperatures, droughts, and poisonous seed and chemical conditions. High molecular weight polymers are ideal for use as additives because they have excellent water solubility and activity, restricted heat transfer, good rheological qualities, a non-toxic chemical origin, and good rheological properties. Liquid inoculants have a number of benefits, including ease of handling and application to seeds, compatibility with modern agricultural machinery, size reduction due to the need for less inoculant, ease of production, packaging, and storage with longer shelf lives, higher cell counts, higher performance in soil, the elimination of contamination issues, and cost effectiveness because it doesn't need to be processed and sterilized of solid carrier material[8].

Formulation Based on Polymers

Further research efforts targeted at enhancing the stability and shelf life of biofertilizers have been motivated by the growing interest in the use of biofertilizers as plant protectants. Polymer-based carriers have been created as a consequence of these investigations. In this procedure, the microbial cells are first immobilized by the polymer in the matrix before being progressively released. Because they provide defense against environmental pressures, these formulations benefit from a longer shelf life even when stored at ambient temperature. Due to the regulated manufacturing process, polymer-based formulations also guarantee the creation of goods with uniform quality. To maintain the viability of the encapsulated cells for a long time, it is advisable to store the inoculant at a temperature of 4 °C. To boost the bacteria's capacity to survive while being applied, the inoculants may also be supplemented with additional nutrients. Alginate-based formulations are being utilized more often as a result of their advantageous qualities, including biodegradability, nontoxicity, and slow release of microorganisms into the soil. However, the expensive cost of alginate is a significant disadvantage to its utilization. Pseudomonas fluorescens and Azospirillum brasilense have been effectively inoculated into wheat plants under field circumstances using alginate as the encapsulating agent.

For alginate-encapsulated bacteria during field inoculation, longer survival rates comparable to values achieved using alternative carrier-based inoculants have also been reported. The fluidized bed dryer formulation strategy for biofertilizer preparation may be able to solve the issues of contaminated biofertilizers and their short shelf life. Contaminants may be decreased by lowering the moisture content of carrier-based inoculants. By optimizing the manufacturing of dried inoculants, it is possible to increase their shelf life and their inoculant activity under field circumstances.

In general, the FBD creates a fluidized condition by suspending the injected material against gravity using an upward air stream. The decrease in drying temperature is a significant benefit of employing the FBD for bioinoculant drying. Even lower temperatures make it feasible to dry products, enabling the drying of more temperature-sensitive organisms. These temperatures range from 37 to 38 °C. More study is still required on the use of fluid bed dryer for the manufacturing of biofertilizers, despite the remarkable potentials of FBD. The lack of contamination, flexible drying temperatures, little cell population loss, and the combination of many substances before drying are further benefits of FBD.

A brand-new technique that makes use of the characteristics of supercritical fluids is the procedure for separating particles from gas saturated solutions. Carbon dioxide is used as a supercritical fluid in the low-temperature PGSS process. This approach has the potential to both lower manufacturing costs and develop formulations that have no detrimental impact on the viability of the microorganisms. Particles that are virtually spherical in shape and are in powdered-like shapes that can be suspended in water are the final result of the PGSS process. The effectiveness of this technique for encapsulating viral formulations has been examined. Other effective PGSS technique applications have been carried out for various solids and liquids.

Modes of Application for Biofertilizers

The soil may be fertilized using biofertilizers in a number of ways. One of the application strategies is:

a. The sprinkle technique, which entails lightly moistening the seeds in water before combining them with peat powder.
b. Seed vaccination using powder formulations
c. In the seed hopper, combining seeds and dry biofertilizers
d. The slurry approach, which includes dissolving the fertilizers in water before incorporating them into the seeds.

Treatment of Seeds

The approach utilized to administer different kinds of inoculants is this one. It is a highly cost-efficient and effective method of application. The seed treatment procedure essentially entails evenly covering a combination of seeds in a slurry, drying them in the shade, and planting them within 24 hours. However, depending on the amount of seeds involved, seed coating with liquid biofertilizers may be done using a bucket or plastic bag. The plastic bag can be used for little amounts of seeds, but the bucket may be utilized for larger amounts of seeds. The seed treatment ensures that the right quantity of bacteria is delivered to each seed in order to produce the desired outcomes while also allowing the use of various bacteria combinations without any unwanted effects.

Application to Soil

The biofertilizers are applied directly to the soil using this technique. It may be used alone or in conjunction with other bio-fertilizers. For instance, rock phosphate, cow dung, and phosphate-solubilizing biofertilizer have been blended and held overnight in the shade with their moisture content preserved at 50% before being applied to the soil. The following benefits of soil applied inoculants over powder form include elimination of seed mixing, reduction of direct contact with treated seeds, ability to increase delivery rates, providing more rhizobia per unit area, and improved ability to withstand low moisture conditions. Rhizobium and Azotobacter are two examples of biofertilizers that have been administered using the soil application approach.

Influences the Making of Biofertilizers

The cost necessary for manufacture is a significant component that influences the development of biofertilizers. In order to maintain market sustainability, the market price for biofertilizers is anticipated to be on par with or even lower than that of conventional fertilizers. When making biofertilizers, it's also crucial to take the inoculant formulation into account. The following factors, according to Sahu and Brahmaprakash, should be taken into account while producing biofertilizers:

a. The inoculant created should be simple to use in terms of application and handling.
b. The inoculant formulation should be delivered to the target locations in an effective way and format.
c. The biofertilizer that is created should be able to protect the agent from a variety of environmental hazards.
d. The inoculant formulation should be capable of enhancing or maintaining the microbial activity of the soil.

e. Throughout the processes of manufacture, distribution, storage, and transportation, the stability of the inoculum formulation is essential.
f. The biofertilizers created should be able to enhance soil characteristics and withstand pH fluctuations while being stored.

The Advantages of Biofertilizers

When you take into account the issues associated with the usage of chemical fertilizers, using biofertilizers offers a number of advantages. Leaching, the eradication of microbes and other crucial eco-organisms, water body pollution, crop vulnerability to disease, and decreased soil fertility are a few of these issues. However, using biofertilizers may assist in overcoming these difficulties. In addition to lowering the demand for inorganic fertilizers, biofertilizers have the potential to meet the nutritional needs of plants. By using bio inoculants, biofertilizers may help plants thrive and increase food harvests. There are several strains of live microorganisms in these bio inoculants. These bacteria are able to mobilize and change nutrients from an inaccessible form into one that can be used in the rhizosphere. They can also make it easier for complicated organic molecules to break down into simpler ones that act as nutrients, enhancing soil fertility and boosting crop yields while preserving soil ecology.

Numerous plants benefit from biofertilizers in terms of growth and output. Malusà et al. found that when used in conjunction with organic and inorganic fertilizers, microorganisms that aid in plant development may be employed to efficiently improve plant nutrition. Higher crop yields from the application of biofertilizers were reported by Bhardwaj et al. as a consequence of an increase in the protein content, vitamins, amino acids, and nitrogen fixation. Biofertilizers continue to be a desirable alternative to chemical fertilizers due to their eco-friendliness, non-toxicity, ease of use, and affordability. Additionally, biofertilizers may augment agrochemicals by converting naturally occurring nutrients from the air or soil into plant-usable forms. Other advantages of using biofertilizers in agriculture include improved post-harvesting of crops, cleanup of heavy metals and crude oil contaminated soils, increased vigor in seedlings and adult plants, excellent source of micronutrients and micro-chemicals, secretion of growth hormones, and source of organic matter.

Limitations and Issues with Biofertilizers

The inconsistent nature of biofertilizers' efficacy is one of its main drawbacks. Further advancements are required to guarantee the consistency of biofertilizers' functioning in order to maximize their use in agriculture. Additionally, there is a hole in how inoculants are created and used. This is mostly because the companies that make these vaccines are unable to take into account the special difficulties that arise when the vaccines are used in developing nations, which make up the majority of their target markets. The use of biofertilizers in certain soil conditions, such as semi-arid environments, is another constraint. Due to the existing unfavorable circumstances, which include but are not limited to drought, excessive salinity, inadequate irrigation, and soil erosion, when applied to semi-arid environments, the survival rate of the introduced bacteria is extremely low. Additionally, the competition from native strains of bacteria may prevent the newly imported bacteria from properly populating the rhizosphere. More information is needed on the elements that govern competition between bacterial strains, particularly in natural environments[9].

The production of inoculants with poor quality and low nutrient density, an ineffective inoculants delivery/supply system, poor sensitization and education of farmers on the use and benefits of biofertilizers, and a lack of concerted effort in terms of policy to ensure the utilization of biofertilizers are additional factors limiting the application of biofertilizers.

Future Possibilities

The use of biofertilizers will continue to be a crucial component of this effort as the desire for greener, cleaner, and more sustainable agricultural production techniques rises. Consequently, better biofertilizer formulations will be created as a result. It is safe to assume that in the years to come, the continuous and widespread utilization of biofertilizers will provide several useful insights for the full improvement of the agricultural sector given their growing popularity and successful applications in a number of countries. The formulation, storage, and application of the bio inoculants will need in-depth studies and the creation of innovative methodologies in order to produce biofertilizers for large-scale commercial use based on laboratory and greenhouse tests. extensive education and awareness-raising of farmers and other stakeholders on the usage of and long-term advantages of biofertilizers instead of utilizing chemical fertilizers, as well as the inherent risks associated with the continuous use of chemical fertilizers to life and the environment. To eliminate the myth that bacteria are primarily used as disease-causing organisms, a paradigm shift in public perception will be necessary.

The creation of genetically altered bacteria strains that are very effective and efficient in increasing plant growth will be required, as opposed to the present biofertilizers, which are often generated from carefully chosen non-transformed bacteria strains with particular desired features.

However, the public and environment must be adequately assured by the appropriate regulatory organizations that such innovations do not pose any risks or hazards. Additionally, a quality control system will be sufficient to keep track of how inoculants are produced and used. Establishing strict laws and rules for quality control over the use of biofertilizers is necessary. In addition to agronomic and economic assessments of biofertilizers for various agricultural uses, research on the adaptation of microorganisms in biofertilizers under challenging environmental soil conditions should be conducted.

CONCLUSION

Biofertilizers are an extremely desirable and viable source of nutrient supply to plants that is eco-friendly and economical, with potential for wider agricultural applications due to the numerous advantages associated with their use in terms of plant growth and productivity as well as the added protection against some plant diseases. Finding the most beneficial plant-microbe interaction is essential for increasing output. In addition to identifying the different strains of biofertilizers and their properties, further research must be done to comprehend the true mechanism of biofertilizers. To attain clean, green, and sustainable agriculture, more durable and effective biofertilizer formulations will be created as biotechnology advances. Improved, simple-to-use inoculant formulations that are economical, stable, and usable will undoubtedly result in more widespread use, application, and public acceptance of biofertilizers.

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CHAPTER 17

WASTE-BASED BIOFERTILIZERS

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ABSTRACT:

In addition to adversely affecting human and animal health during the last several years, the extensive use of chemical fertilizers has caused major environmental problems. According to some estimates, these compounds substantially degrade soil quality and agricultural yield in addition to contributing up to 10% of the world's greenhouse gas emissions. An increasing awareness of the usage of sustainable goods, which pose less risks than synthetic ones, has made biofertilizers the primary replacement for chemical fertilizers recently. The environmental effect of land usage is reduced by biofertilizers, which are live microorganisms that, when applied, offer almost all the nutrients required for the development of the cultures. Due to the important biomass production, formulations based on photosynthetic microorganisms, such cyanobacteria and microalgae, are of special interest. Additionally, a lot of studies and research have focused on the creation and marketing of waste-based biofertilizers. Since organic materials are inexpensive and renewable sources of nutrients for sustainable usage, using them as the foundation for the creation of biofertilizers is an ecologically responsible approach to integrated management and waste utilization. In this regard, the goal of this chapter is to provide an overview of biofertilizers by focusing on waste recycling, key sources, suitable treatment procedures, developing technologies, and applications.

KEYWORDS:

Organic waste, chemical fertilizers, waste treatment, bioremediation, nutrient recovery, microalgae/cyanobacteria, sustainable agriculture.

INTRODUCTION

Around 1960, when the green revolution began, intensive agricultural methods were developed to accommodate the enormous demand for grain output while also increasing the crops' resilience to pests and diseases. Despite an increase in the production of food crops, excessive use of chemical fertilizers ultimately resulted in a number of environmental issues, including serious nutrient imbalance, groundwater contamination, salinization, and diminished long-term soil fertility. Along with having a high energy requirement, these items are known to contribute significantly to greenhouse gas emissions. To get over these constraints, it is thus necessary to employ more sustainable goods[1]. Because they are non-toxic, inexpensive, easy to use, and ecologically benign, biofertilizers are now the greatest substitute for synthetic fertilizers. Biofertilizers are microbial substances that may boost the soil's nutrient availability and transfer, colonize plants' interiors, and encourage the development and production of the widest range of crops. Fungi, bacteria, cyanobacteria, and microalgae are the most common types of living microorganisms employed in their construction, together with a transporter material.

There are many different biofertilizer formulations, but those based on organic waste have drawn a lot of interest because of their remarkable capacity to improve soil fertility. In contrast to artificial fertilizers, organic waste, which is mostly sourced from agricultural, municipal, and industrial sources, contains a significant quantity of biological material and vital nutrients. Using biofertilizers based on waste recycling is now regarded as the cornerstone of sustainable agriculture since it uses cutting-edge recycling methods, lessens environmental effect by redirecting greenhouse gases and carbon dioxide, and avoids the expensive expense of landfills. Although only capturing 1% to 2% of the global market, the usage of these bio alternatives is still rather low when compared to the use of synthetic goods. In conclusion, there is still a huge need for innovative strategies and long-term bio economy solutions for the world's most varied environmental problems. Researchers from all across the globe are working to create more user-friendly bio products that address the negative effects of chemicals and are accessible to more cultures, as well as biofertilizers made from trash.

Debris Sources

The production of solid, liquid, and gaseous waste has significantly increased as a consequence of the fast advancement of industrial growth. The issues with waste are mostly caused by the increase in output, the diversity of items being abandoned, and the challenge of locating locations for their deposit or proper disposal. Most nations in the globe now have a substantial difficulty with waste management. In contrast to underdeveloped nations, trash generation is substantially greater in industrialized nations. In actuality, the vast range of sources connected to the most different industries and segments, which have expanded in recent years, are to blame for the rise in these residues. The primary sources of organic waste produced today, which include a variety of chemical, physical, and biological contaminants and which, with correct processing, have the potential to become goods with a high added value, such biofertilizers.

Since there is such a large demand for innovative research and development solutions, agricultural waste creation is now one of the primary sources of attention. Since they are often produced by manure, agricultural and silage leftovers, oil processing, veterinary medications, insecticides, and fertilizers supplemented with carbon and nutrients like nitrogen and phosphate, these residues represent a significant source of pollution, pathogens, odors, and greenhouse gases.

The production of rice, wheat, cotton, and maize are some of the major crops in charge of the majority of this agricultural waste. However, as animal excrement is often dumped into estuaries and rivers without any pretreatment, it is also a substantial source of pollution. According to reports, these leftovers account for 20% of all global methane emissions, making them one of the most significant sources of greenhouse gas emissions. Each town generates a significant volume of waste water each year, which is rich in nutrients and organic elements. Cleaning supplies like detergents are estimated to provide roughly 0.03 tons of the major residual loads in municipal treatment facilities. Human garbage, in comparison, produces around 0.06 tons per capita per year[2].

The pharmaceutical business, the manufacture of paper and wood, and the creation of fermentation products are only a few of the industrial sectors that produce other significant residual volumes. Industrial waste has a strong odor due to the presence of organic fillers and volatile compounds, as well as high chemical and biological oxygen demands. However, many nations currently mandate that businesses utilize the right technology to lower the content of these residual contributors. Each trash has its own typical components, which might vary based on the time and operating circumstances, despite the fact that they share certain features. For instance, the main pollutant in any garbage is organic stuff. BOD contains biodegradable components, while COD just includes total degradable substances. Additionally, although phosphorus is often available in the form of phosphate, nitrogen is mostly present as ammonia.

Standard Technologies

The development of biofertilizers in conjunction with waste treatment has received a lot of attention, but each kind of composition requires a different design and operation of the treatment process. An early treatment, which involves the removal of suspended particles and floating materials, summarizes the earliest phases. After this stage, the processes intensify and are dependent on the microbial degradation of organic molecules. Numerous different setups are shown here. However, the use of activated sludge as a treatment method is highlighted for having a number of benefits, primarily because of its cheap operating cost. In turn, tertiary treatment is an extra process that may lessen the waste's nitrogen and phosphorus content. The nitrification-denitrification process is the principal method of nitrogen removal. In contrast, the employment of chemical processes and fertigation has recently been utilized to minimize the compounds in the removal of phosphorus in addition to biological processes. The review of present treatment methods concludes by highlighting the high costs of chemicals and energy as well as the increased need for labor, technology, and procedures due to the ongoing expansion of treatment facilities. Additionally, as certain transformation processes might put additional strain on the system, the excessive generation of pollutants in the atmospheres must be evaluated. Based on this, a novel idea for creating and improving cutting-edge technologies must be assessed in order to address present issues[3].

Future Technologies

The topic of how to lessen the need for chemical fertilizers arises in light of the assumption that excessive use of these fertilizers harms the soil, unbalances and decreases nutrients like N, P, and K, contaminates groundwater, and raises salinity. What technological advancements may help real agriculture flourish sustainably? Many scientists have shown a significant deal of interest in these questions. There are many different kinds of biofertilizers available today, but those based on photosynthetic bacteria are of special importance since they produce important biomass. In comparison to traditional technologies, cyanobacteria and microalgae have been exploited as new technologies in contemporary agriculture. Biofertilizers may also be made using fungus and bacteria, in addition to other microorganisms. Instead, the range of applications for these distinct types of microbes has increased. They are able to collaborate, leading to the formation of a consortium between cyanobacteria and bacteria or between cyanoalgae and bacteria, or between their respective biofilms.

Microalgae and cyanobacteria, which are bacteria, can both ingest large quantities of nutrients from waste in various ways, including phototrophically, heterotrophically, and mixotrophically, and then transform them into a variety of products of interest to industry. For instance, a large category of organisms known as microalgae, which are ideally photosynthetic, utilize light energy to bioconvert nutrients into organic matter in order to produce biomass. Due to its unique structural, physiological, and morphological traits, it may be used in a variety of processes to produce goods including food, medicines, biofuels, bioenergy, animal feed, and, most significantly for agriculture, natural fertilizer.

Microalgae and cyanobacteria are capable of recovering and recycling the nutrients found in wastes to increase biomass productivity and then target your ultimate use. For instance, dry biomass-based waste sewage and manure may be produced at a rate of 1 and 10 kg per m3, respectively. This indicates that the method for nutrient cycling from trash using microalgae has been effective. However, it is important to assess that this kind of technological path is only dependent on a consortium of the connected microalgal/cyanobacterial vs bacteria when taking into account the utilization of microalgae for waste bioremediation. A diverse population of different kinds of microorganisms that work together in microbial consortia to possibly be used in trash biodegradation. They increase the variety of enzyme activity associated to xenobiotic compounds in the media, resulting in a wider range and faster rates of breakdown. According to several research, the collaboration can successfully implement large COD, NH3, and P removal rates in laboratory-scale systems[4], [5].

They generate biomass and release oxygen, which bacteria need to convert organic molecules into inorganic chemicals. Assimilation, anaerobic ammonia oxidation, nitrogen nitrification and denitrification, and phosphorus absorption all contribute to this. In this simplified diagram, the bacteria produce CO2, which microalgae ultimately eat. The operating settings in the bioreactor are determined by the natural equilibrium between the connected microalgae and bacteria. Although the consortium seems straightforward, microalgal and bacterial metabolisms entail complex metabolic processes. The formation of biomass via photosynthesis and the release of hydroxyl ions by the absorption of nitrate and reduction to ammonia are the two primary processes involved in microalgae-based metabolism. In contrast, microalgae ingest smaller organic molecules like short-chain carbohydrates via heterotrophic metabolism. For growth, nitrification, denitrification, and biomass production/decay, bacteria use aerobic metabolism.

Regardless of metabolic processes, it is important to keep in mind that light intensity, pH level, temperature, inoculum and nutrient concentration can all have a significant impact on how well microalgae and cyanobacteria perform during nutrient recovery processes from wastes. These in turn will vary depending on the algal strains utilized, the kind of bioreactor, and the mode of operation. The primary determinant of these processes is light availability, which relies on location, photoperiod, and solar radiation as well as the depth of the cultivation system. Numerous studies support the significance of this parameter for both recovering nutrients from waste and the overall efficiency of microalgae-based processes. For instance, a bioreactor with a shallower depth will have greater light irradiation levels, which will promote culture development and nutrient uptake. It should be noted that this suggests a smaller bioreactor, which allows for the treatment of lower waste loads.

Accurately determining the system depth is crucial for growing microorganisms. The creation of high-quality biomass, for which it is recommended that the culture depth be less than 0.2 m, and the treatment of heavy waste loads, for which a depth larger than 0.3 m is required, should be balanced out, however. On the other hand, if the cultures are exposed to great depths, the light incidence may be insufficient for the microalgae to assimilate the produced CO2 and, as a result, the nitrification/denitrification phenomena would occur excessively, allowing bacteria to produce oxygen and oxidize organic matter. Photosynthetic efficiency has an impact on cell development and biomass production in addition to light. This element is reliant on the medium's suitable pH and temperature. According to certain research, the pH varies under illumination and when CO2 is not present, reaching levels around 9.0. This is a result of microalgae assimilating CO2 and NO3. Later on, however, the pH value drops as a result of the bacteria's emission of CO2 and H+ ions. Therefore, it is essential to understand the factors that influence these systems. The makeup of the waste may also influence how well microalgae and cyanobacteria assimilate nutrients, making it crucial to understand the variables that influence these systems. By maximizing and simulating the production of the microorganisms, it is possible to maximize the removal capability of the nutrients present in the wastes. Additionally, it's important to comprehend the technologies utilised in these bio-processes' processing steps.

Process Operations Overall

Numerous unit actions make up the microalgae's recycling of nutrients from waste. Waste pre-treatment, nutrient recovery, biomass generation in the bioreactor, harvesting, waste treatment for recirculation or ultimate disposal, and getting microalgal bio-mass for conversion into the intended target product are the primary processing processes. A process flow diagram of these stages is shown in Figure 17.4 in a short manner. The first two phases, which include pre-treating trash and recovering nutrients, are similar to those used in traditional waste treatment facilities. In order to increase the quality of the residue, it is important to filter the total solids with the goal of lowering turbidity. Additionally, if the solids removal during the biomass harvest is enough, the waste treatment is skipped. Additionally, because harmful bacteria are present in microalgae-based processes in low quantities, additional disinfection procedures are dropped before recycling or releasing the clean waste into the environment.

The bioreactor culture stage and harvesting are regarded as being the two steps that are most important for producing biomass from microalgae. Numerous studies illustrating different reactor designs and operating circumstances for the culture of microalgae, such as open and closed systems, can be found in the literature. However, open systems are the most often researched for waste recovery. Since the 1960s, open bioreactors have been used. Different types, including circular ponds, shallow lagoons, mixed ponds, and inclined systems are now being researched; nonetheless, raceway ponds are often employed for commercial reasons. A paddlewheel is used to move them in order to maintain the flow of the microalgal broth and to periodically expose the cells to light radiation. They are distinguished by large culture reservoirs, low depths, and typical cell residence durations of 8 days. Raceway ponds are easier to scale, less expensive, and simpler to construct. Large-scale systems up to 5,000 m2 are employed nowadays. In spite of the fact that there aren't many design flaws, this component of the system is nevertheless important since increasing productivity is the main goal of any cultivation method. Although the raceway ponds' efficacy in treating waste has been shown, a number of further enhancements have been suggested. The main assertions relate to fluid dynamics and the mass transfer coefficient.

Harvesting is done to retrieve the cells diluted in the broth once culture is finished. In raceway ponds, cell concentration is typically low and cell size is small. Therefore, it is difficult for present harvesting technology to extract as much biomass as feasible. Centrifugation, filtration, flotation, sedimentation, and electrical processes may all be used to concentrate it. Since centrifuges have a recovery rate of up to 95%, they are more often utilized for dewatering microalgal broth. However, the amount of water that must be evacuated makes them very energy-intensive. A third of the cost of producing biomass is reportedly accounted for by the harvesting methods now in use. Given this situation, technologies with lower energy demands must be included into the processing of microalgae biomass in order to recover nutrients from wastes.

The use of microalgae-based processes to treat various wastes together with the generation of biomass for use as market-relevant inputs is, lastly, a fast expanding sector, independent of the upstream and downstream processing stages. Numerous businesses across the world are striving to manufacture biomass as an agricultural product. The potential possibilities for this include biofertilizers. We'll talk about how it applies to current agriculture below[6].

Principal Uses of Microalgae-Based Fertilizers

Applying a resilient supply of nutrients to agriculture is essential for success in rural areas without endangering the environment or the national economy. Biofertilizers are gaining popularity as a result of a focus on the development of sustainable agriculture since they may increase crop fertility while also reducing the aggravation caused by real fertilizers. Currently, there is a commercial need for microalgae bio refineries, which have enormous potential as bio-resources for various industries. By processing their waste and creating bio products, these residues have the potential to be used as biofertilizers in a symbiotic system to enhance soil structure and help replace chemical fertilizers.

These microorganisms are already used in agriculture, and they are very capable of dispersing nutrients from the soil, enhancing soil quality and macro- and micronutrient content. They can also manage pests and illnesses and create hormones, carbohydrates, and antimicrobials. Only particular kinds of microorganisms can fix nitrogen, including bacteria and microalgae, which contain nitrogenase systems known as heterocysts. As a result, these organisms don't compete with plants for nitrogen and instead enhance the soil's availability. According to studies, using microalgae may decrease the need for artificial nitrogen fertilizers by 25% to 40%. Rice crops may use up to 50% less chemical fertilizers when microalgae are used as biological nitrogen fixers, according to Pereira et al., without suffering any impact on grain quality or yield. By using cyanobacteria as biofertilizers in pea plantations, Osman et al. also came to the conclusion that using cyanobacteria may cut fertilizer consumption by up to 50% while still improving the nutritional content of peas.

In addition to having an economic benefit by decreasing the costs of chemical fertilizers, the use of microalgae biofertilizers enhanced agricultural production in a number of other crops, not only rice. Leaching, a process in which nutrients leak out of conduits in the fields, is a possibility, thus environmental protection is required. Although Mager and Thomas claimed that exopolysaccharide molecules produced by microalgae are what cause biological crusts to develop in the soil, their contribution to immobilizing access to N is far less than that of the leaching brought on by routinely used synthetic fertilizers. As a result, using microalgae may result in cheap production costs, less pollution, and no leaching.

Sequestration of Carbon

Nitrogen and carbon dioxide emissions, which are also released from the soil when chemical fertilizers are applied, are increased by their usage. Since microalgae are organic matter sources and are directly connected to the absorption of atmospheric carbon dioxide via photosynthesis, they may greatly enhance the organic carbon content of the soil, making their use necessary. Further research into these fixation processes is required since improved carbon fixation in the earth may help with environmental damage repair. The development of biological scabs in the soil appeared to hold promise. These scabs, which are composed in various ratios of microalgae, microorganisms, and fungi, restore ground nutrients and balance the ecosystem while acting as a significant carbon storage facility in the soil. The results showed that, compared to the control, the alterations of the ground with the application of microalgae biofertilizers enhanced the organic carbon of the soil. This potential of various kinds of biofertilizers in the organic carbon of the soil. Hence, it can be seen that microalgal biofertilizers are an advancement for better nutrient absorption, benefiting the environment[7].

Sustainable farming is fundamentally dependent on the preservation of a suitable standard of organic components as well as the structure and composition of the soil. The synthesis of organic matter and the Solubilization of nutrients in the soil, which are crucial for the growth and evolution of plants, are two additional ways that microalgae contribute to the advancement of the ground's organic material. The high level of organic carbon produced by these microbes contributes to the proliferation of flora and animals. The degradation of microalgae biomass causes the soil's organic content to increase. Studies on the use of microalgae in the soil and in various cultures revealed an improvement in the biochemical characteristics and overall organic material. Algae, more especially cyanobacteria, have a role in mineralization not only via the production of organic acids but also through the production of siderophores, which are chemicals produced by microbes that chelate ferric iron to make it available to plants in times of iron deficiency.

Studies on the bio fortification of basic and food crops using microalgae report that the application of microalgae results in changes to the frame and expands microbic species involved in processes of Solubilization and mineralization. These studies also report that the application of microalgae leads to changes in the nutrient content of plants and seeds. Studies on the bio fortification of basic and food crops using microalgae report that the application of microalgae results in changes in the structure and expands microbial species involved in the processes of mineralization and Solubilization of nutrients. These studies focus on the enrichment of micronutrients, particularly Fe, Mn, Cu, and Zn in plants and grains. Different weather conditions have the potential to harm the soil, which ultimately reduces agricultural production and fertility. Exopolysaccharides, which are produced by microalgae, are a mechanism that enhances soil microbial activity by supplying organic carbon and creating bioflocs and biofilms, both of which are crucial for the rhizosphere.

Since microalgae were used in the three-stage sewage treatment process and considerably enhanced the organic matter, mostly carbon, following treatment, they may aid in soil regeneration. Microalgae are connected to the restoration of places that have been damaged by oil, according to Abed as well. The stress tolerance of rice crops to fly ash was increased by Tripathi et al.'s use of microalgae as a biofertilizer in soil mixed with fly ash, and these avoided the buildup of heavy metals in plants, having a positive effect on plant development. Microalgae may thus be used as biofertilizers, inoculants, and in the recovery of polluted soils.

Plant Growth Promotion, Disease Prevention, and Pest Control

Hormone production and plant colonization

Microalgae may be used as plant colonizers and offer various advantages for the soil, as was previously described in the preceding sections. It has been observed that microalgae infiltrate epidermal cells, intercellular gaps, cortex, sub-stomatal chambers, and create intracellular loops. Several species of microalgae have symbiotic relationships with various plants. Numerous plant components may be colonized by cyanobacteria, which can also play a role in defense, nitrogen fixation, nutritional status, and growth. A symbiotic production of chickpeas was also produced by using microalgae inoculants, offering advantages in the soil content, boosting soil fertility, and enhancing the harvest. Phytohormones are crucial for promoting the development of plants; in agriculture, there has been an increase in the addition of plant hormones to promote weed control and aid in the growth of crops. The internal hormones found in microalgae allow them to produce and/or excrete these substances into the environment or the growth media. The hormones that these microorganisms release for the growth of plants in sterile areas demonstrate the levels of cytokines and aid in having a beneficial effect on plant growth. This interaction takes place via microalgae contact/roots. The levels of auxin in wheat rose when microalgae was used as a phytohormone supplement in the research, indicating that there is a beneficial transfer between microalgae and wheat.

There aren't many small-scale studies that employ algae as hormones, but more research is required before it can be used in a way that's good for the environment.

Control of Disease and Pests

Microalgae may be used to communicate plant defense processes, particularly antioxidant functions. Microalgae greatly boosted the activity of enzymes that protect plants both in the source and in the aerial section of rice plants. By examining enzymatic activity, microalgae usage helped plants' immunity in a positive manner. Examining the true potential of microalgae as a biofertilizer reveals a range of uses and the unique characteristics of each species. The use of these shows a considerable rise in both the enzyme activity of nutrient-assimilating enzymes and the defensive response of plants, such as increased RNA. Microalgae also have another use: they may be used to lessen plant pest populations. By reducing the amount of nematodes in tomato seedlings by up to 97.5%, cyanobacteria was able to increase productivity.

Before alterations in the antinematocidal function, the usage of these microbes was more successful in stimulating plant development. When compared to the use of chemical fertilizers, the use of biofertilizer microalgae resulted in a decrease in the number of mosquitoes in the field, resulting in improved growth. Additionally characterized as antifungal, insecticidal, nematicidal, and herbicidal were metal extracts of microalgae. So that we can successfully apply these microorganisms in conventional agro-industrial practices and their action has a successful integration with common agricultural practices, more research is still required to determine strategies in applications of these microorganisms as biofertilizers and or their combined use [8].

CONCLUSION

To prevent the negative issues brought on by fertilizers and chemical goods, several governments throughout the globe are promoting the inclusion of sustainable initiatives and advances. To encourage organic farming and eventually combat environmental contamination, several nations are establishing policies and initiatives. According to recent market research and strategy studies, the biofertilizer industry will expand over the next several years and might account for USD 3 billion in sales.

The utilization of cyanobacteria and green microalgae as biofertilizers has been proved to have significant promise. In addition to being non-toxic, pathogen-bio controlling, and cost-effective, microalgae biofertilizers have a shown ability to restore soil nutrients. However, the cost and costs associated with biomass production are entirely responsible for the success of the production of microalgae biofertilizers. In this sense, using organic residues to create biofertilizers is a smart move since it benefits both the environment and the economy. Microalgae-based nutrient recovery is a secure method that may be used to various wastes. By minimizing the demand for energy and greenhouse gas emissions, the generation of these microorganisms at the same time as waste treatment has a significant influence on both processes' sustainability and the cost of treatment. Presenting these techniques, which can be implemented on an industrial scale and are economically feasible, is the major act of disobedience today.

Finally, further research and demonstration-scale testing are still required before microalgae biofertilizers produced by wastes can be marketed owing to their difficulties. Emerging fields that need study include the rise of high-value features and how they are used in agriculture. In order to validate the use of biofertilizers and boost their commercialization, new molecular methods and the development of genetically modified microorganisms are revealing fresh information about the pathways involved in interactions with soil and plants. Further study and understanding of environmentally friendly items are also urgently needed to maximize the potential of your investment in the future.

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CHAPTER 18

MARKET PROFILES FOR THE BIOFERTILIZERS INDUSTRY

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ABSTRACT:

The attractiveness of the agricultural sector is being driven by the steadily expanding population and rising earnings in both urban and rural areas. A data consensus analysis also confirms that fertilizer directly contributes roughly 50% of the industry's total share in agriculture. Numerous governments and other organizations are actively sponsoring research and development in this field in light of the needs of the whooping industry. The goal of authoring this chapter is to inform readers of the current state of biofertilizer and to inspire participation in efforts to meet food demand goals in an environmentally responsible and sustainable way.

KEYWORDS:

Biofertilizer Market, Bioavailability, Green Fertilizers,Liquid Fertilizers, Rhizosphere.

INTRODUCTION

Microbial inoculants or bio-formulations are other names for biofertilizers that are often used, although the word also has many other synonyms, including manure, green manure, organic supplemented or intercrop, and chemical fertilizer. According to Vessey, a biofertilizer is correctly described as a substance that contains living microorganisms that is applied to seeds, leaves, roots, or soil to allow the colonization of the rhizosphere and thereby promote growth by increasing the supply or bioavailability of the major nutrients to the host plant. The term "PGPR" was initially used in 1978 to describe a collection of microorganisms that are generally free-living bacteria in the soil, rhizosphere, phyllosphere, and other environments. These bacteria are very beneficial to plants and thrive in certain environments.

Advantages of Various Biofertilizers

As a Supplement to Chemical Fertilizer: Biofertilizer has the ability to increase output quickly, but because of its limitations, it is not recommended for casual usage. It is used in conjunction with chemical fertilizer, or more precisely, as a complement to chemical fertilizers using biofertilizers. High Crop Production: It can fix biological nitrogen in the soil, is easily accessible to the host plant, can enhance soil characteristics, and can maintain soil fertility. On average, it enhances crop output by 4% to 5%. It is a productive source of nutrients that upholds and supports production and quality[1].

Due to its nutritional value, less environmental effect, and renewable supply, use of biofertilizer is on the rise. By raising the organic content of the soil, biofertilizers improve the soil biota and benefit plant health. Economic Reasons: Compared to chemical fertilizers, biofertilizers are less costly and may significantly lower crop costs. It is beneficial in particular for cereal crops and offers plant nutrients at a cheap cost. Biofertilizers based on microbial inoculants are used to reduce dose requirements while providing an economic boost to crop output. Restoration of Soil Structure: Biofertilizers have enormous potential for preventing soil illnesses and drought. As an alternative to chemical fertilizers, it is efficient and environmentally beneficial. Additionally, biofertilizers have the ability to protect the host plant from abiotic stress. It offers a fantastic substitute for meeting the nitrogen needs of crops.

DISCUSSION

Insufficient knowledge of the market's situation and potential for biofertilizers. Furthermore, the farmers and crop producers are oblivious to it and more willing to accept it as a necessary component of agricultural plantations. It is still only possible to use biofertilizers in certain crops and regions to successfully and effectively integrate them into farmers' fields. The majority of microbial activity has host- and site-specific applications. Because they are living microorganism inoculants, biofertilizers often lose their activity or die off as the temperature changes. One of its main commercial restraints is low shelf life. Due of their short shelf lives, biofertilizer agricultural products are difficult to market. According to reports, packaging, labeling, and price requirements are not followed, which causes havoc, declines in quality, and losses for farmers.

The government's unsystematic system of subsidies is partly to blame for the encouragement of prejudice and manipulation. Additionally, certain state governments may provide subsidies worth up to 50% of the sales. Although bio-fertilizer offers many benefits for sustainable agriculture, it is less common in India due to limitations at many levels, including the manufacturing unit, farmers' fields, and distribution units[2].

The market is shrinking because to a lack of acceptable carriers for biofertilizer. The biofertilizer's carrier serves as the medium for efficiently loading the microbial inoculants that are utilized. A high-quality carrier guarantees the creation of a high-quality biofertilizer. Since excellent quality carrier peat is not readily available in India, lignite and charcoal, which are often used unsterilized, have been developed as substitutes. Due to the untrained workers involved in the manufacturing process, biofertilizers offered in markets have major contamination issues and a poor MO count. In general, producers lack the necessary skills to employ host-specific strains for a particular biofertilizer's manufacturing, which results in a reduced biofertilizer's efficacy when applied. False manufacturers are supplying subpar bio-fertilizer goods, which lowers consumer acceptance of innovative products.

Segments of the Biofertilizer Market

Based on varieties: In the Indian market, biofertilizers that fix nitrogen, phosphate, and potash are the three most popular varieties. The best alternatives to the commercial nitrogen fertilizers now on the market are nitrogen-fixing biofertilizers. Fertilizers based on nitrogen are heavily marketed, particularly for crops like rice, oats, and cereals. Because rice is a staple crop in many Asian nations, including India, China, Japan, and Indonesia, there is a high need for and supply of nitrogen fertilizer. The current state of the nation's production and consumption of various fertilizers is clearly.

According to Crop: The most widely cultivated crops are grains, vegetables, and oilseeds. Cereal crops have the greatest fertilizer needs of all crops. Fruits and vegetables, cereals, plantations pulses, oilseeds, and other crops are among those included in the market for biofertilizers depending on crop. Compared to fruits and vegetables, cereals and grain need a greater quantity of biofertilizers. The consumption of biofertilizers for vegetables and fruits, which is the second main use, expands their potential.

India's Biofertilizers Market Drivers

Growing environmental consciousness, increased organic demand, and need for improving soil fertility may all be major biofertilizer industry drivers. On the other hand, inadequate benefit understanding and a consequently lower adoption rate by farmers are identified as limiting reasons for the hurdles to the market's exponential expansion for biofertilizers. The demand for fertilizers is not being met by the existing level of output, according to the fertilizer market's current situation. Governments and nations with agricultural economies are developing a range of strategies to raise awareness of the sector and put plans into place[3].

Sustainability: The green revolution greatly increased agricultural production productivity, but regrettably it did not address the sustainability of agricultural expansion. In addition to great crop output, this revolution's unrestrained use of chemical fertilizers and pesticides has resulted in a major loss in soil quality, fertility, and the disruption of the normal microbial flora. In these situations, biofertilizers are like a miracle cure that can utilize different resources effectively for a high-yield, sustainable crop.

Food consumption is closely correlated with the rate at which the population is growing. Biofertilizers may be the best option for feeding such a big population, particularly when the agricultural sector is experiencing significant difficulties as a result of environmental stress. Considering the advantages and potential of biofertilizers, it is crucial to use them alongside cutting-edge agricultural techniques. Second, users are now more informed and knowledgeable thanks to increased awareness of India's organic industry. The manufacture and use of biofertilizers are becoming widely accepted and adopted by farmers and ordinary people. Its rapid expansion has been caused by a strong demand from both a health and economic standpoint. India is a developing nation with a large quantity of fertile land, which makes it a popular destination for both domestic and foreign investors. The Indian government is working very hard at both the state and federal levels to expand the usage of biofertilizers in the agricultural sector.

Current Biofertilizer Market Situation

In terms of Indian agriculture, there is little question that chemical fertilizers have played a significant beneficial impact. The last ten years have seen a significant increase in fertilizer use. In India, a new agricultural paradigm and methods including biofertilizers, bio pesticides, organic farming, low input agriculture, and sustainable agriculture have been encouraged by the need for sustainability. Integrated agricultural methods are often used as indicators of both developed and developing countries. India's gross cultivated area exceeds 190 million hectares, more than enough to meet the country's projected need for 627,000 million tonnes of biofertilizer. Eminent scientist N.V. launched India's first commercial biofertilizer in 1956. Joshi. Agriculture now includes ecologically sustainable practices as of the ninth five-year plan. The Government of India has largely implemented a well-known national initiative on the study, development, and use of biofertilizers, for both production and consumption of biofertilizers. The National Biofertilizer Development Center in Ghaziabad, Uttar Pradesh, which offers training programs in biofertilizer development, is being pushed at the national level[4], [5].

The Department of Biofertilizers sanctioned these units, while the Department of Agriculture and Cooperation sanctioned 74 units. The many private businesses, entrepreneurs, and organizations proposed around 39 units. The country's estimated ability to produce biofertilizers grew to around 18,500 tons annually. The employment of biological agents for biocontrol, organic manures, and biofertilizers has been a key focus of the tenth 5-year plan. Although chemical fertilizer usage increased initially as a result of the green revolution, it decreased over time as its effects were seen and made public. The National Centre for Organic Farming's efforts to commercialize biofertilizer had resulted in a demand for rhizobium biofertilizer of about 0.43 MT, and based on gross cultivated area, it is estimated that the demand for bio-fertilizers for various seed and root treatment is about 0.426 MT.

Issues in Promoting Biofertilizers

Since seeds and other inputs are the primary inputs, biofertilizer marketing is a very laborious operation. Farmers' limited adoption of biofertilizers may be explained as follows: The government takes extensive steps to persuade and educate farmers about the vital advantages of biofertilizers. Additionally, only Rhizobium, Azotobacter, and phosphate-solubilizing bacteria are accepted as biofertilizers. The Government of India periodically holds seminars on micronutrients and biofertilizers to educate farmers and persuade them of the importance of these nutrients in crop productivity. Field day farmer’s visits to agricultural institutions are planned and financed by the government in an effort to disseminate the idea of biofertilizer.

Frequently Sold Biofertilizers in the Indian Market

Prices of various biofertilizers are shown together with the variety of microorganisms employed as biofertilizers and accessible to farmers in India. Rhizobia are soil bacteria that may fix nitrogen within root nodules, particularly in legumes. Examples of rhizobia include mesorhizobium, bradyrhizobium, and azorhizobium species. Due to the flavonoid chemotactic produced by legumes upon contact, they develop symbi-otic relationships with legumes.

Azotobacte: Azotobacter chroococcum spp. is a nitrogen-fixing bacterial strain. Is used to promote soil fertility, improve plant nutrient availability, and increase crop productivity. The genus Azotobacteria is capable of producing many hormones, including auxins, cytokinins, and GA-like compounds, which stimulate plant growth. Additionally, it promotes rhizo-spheric microorganisms, protects plants from phytopathogens, increases nutrient absorption, and is a powerful biological nitrogen fixer.

ABacillus, Pseudomonas, and Aspergillus are phosphorus solubilizes. Wide variety of soil microorganisms demonstrate innate ability to solubilize and mineralize the insoluble soil phosphate as well as on easy release of soluble phosphate on metabolism, increasing the bioavailability of the applied inoculants for seeds and crops. These microorganisms have also been tested for global food production with no negative environmental effects. b) A phosphate mobilizer, like Glomus' VA-mycorrhiza. Some soil bacteria have the ability to convert phosphates from various inorganic sources that have accumulated insoluble into soluble form, making them accessible to plants[6], [7].

Current Biofertilizer Trends: Liquid Biofertilizer

The use of liquid biofertilizer has, to some degree, solved the aforementioned biofertilizer constraints. It is more acceptable to farmers and marketers since it has fewer flaws. Agriculturally effective MOs that can fix atmospheric N2 and also solubilize the insoluble phosphates found in soil for high bioavailability make up liquid biofertilizers in the first place. Liquid fertilizers are becoming more and more popular on the market, where they are working as a viable substitute for both chemical and organic fertilizers. The microorganism in biofertilizers not only promotes plant development but also creates a wholesome rhizosphere. For application, liquid biofertilizer doesn't need a carrier. Potential uses for this kind of biofertilizer are found in soilless farming systems, which are a type of contemporary agriculture.

Liquid Biofertilizer's Unique Qualities

The use of chemical fertilizer might be cut by 15% to 40% with the help of such biofertilizer. Liquid biofertilizer works quickly and is readily absorbed by plants. Due to the fact that it lessens their reliance on the weather, small-scale farmers find it to be a very profitable solution.

The shelf life of the liquid biofertilizer is longer, ranging from 1 to 2 years, than the solid matrix-based fertilizer. According to the share that will be contributed in the competitive international market, liquid biofertilizers are anticipated to satisfy the needs of Indian farmers in the production of organic crops. Fermentation is used to create liquid biofertilizers, which increases the likelihood of viable cells surviving on seeds and soil. The application of treatment is documented. It can withstand UV rays and high temperatures pretty well. The fact that it is simple to use helps farmers strongly embrace it. Such fertilizers have the potential to provide significant economic profits[8], [9].

CONCLUSION

Unquestionably, different parts of India have used biofertilizers extensively for sustainable agriculture due to rising food grain output and a growing population. In the last five years, fertilizers have seen double-digit growth. Despite this growth rate, India's average consumption is still substantially lower than that of the majority of other developing and established nations.

Even while not all Indian states have made biofertilizers an integral element of crop production, they nevertheless provide many opportunities for development in the future. More government and non-government efforts aimed at raising farmers' awareness of the value of biofertilizers are likely to be launched in the near future. The knowledge of improved and sustainable fertilizers is greatly aided by social media, such as television, radio, and tailored workshops. Additionally assisting and supporting farmers, contract farming has a significant impact on the nation's overall fertilizer usage. Although chemical fertilizers still account for the majority of fertilizer usage in the nation, biofertilizer has a very great potential and future.

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CHAPTER 19

UTILIZATION OF BIOFERTILIZERS IN AFRICAN CONTINENTS RESEARCH

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ABSTRACT:

Beneficial microbes have been shown to be essential for the upkeep of sustainable agriculture, as well as for the proper balance of the ecosystem's structure and soil function. It has been shown that the presence of these beneficial microbial consortia increases the bioavailability of soil and crop soil nutrients as well as soil efficiency factors including soil structure. Chemical fertilizers have been shown to improve soil quality and soil function when used to grow crops on farms, however if they are used excessively, this results in an increase in health and environmental risks. Additionally, a lot of individuals in Africa are now dealing with high levels of malnutrition and a variety of nutritional issues, and high rates of soil infertility are compounded by the issue of everyday population growth. The use of biofertilizer will thus be essential as a typical illustration of a sustainable alternative that might aid in reducing all the aforementioned difficulties and the negative impacts of these synthetic fertilizers. a vital function as a substitute to lessen all the difficulties outlined above and the negative consequences of these synthetic biofertilizers. As a result, the purpose of this chapter is to describe the present state of the use of biofertilizer in Africa as well as their mode of operation. The introduction of several forms of biofertilizer was also emphasized. Additionally, several instances of how the use of biofertilizer has increased agricultural output were provided.

KEYWORDS:

Africa, biofertilizer, malnutrition, health, environment, hazards, ecosystem, and soil functions.

INTRODUCTION

It has been noted that agricultural output is steadily declining in Africa, which may be related to issues like pests and diseases, water stress, potassium, and decreased soil fertility owing to nitrogen and potassium. There have been increased attempts made via active research and development to find innovations that might assist to address all of the problems mentioned above. All of the aforementioned issues have gotten worse due to a variety of agricultural issues, such as unfavorable weather patterns, climatic shifts, a high rate of soil nutrient depletion, a high rate of soil erosion, a high rate of leaching, a high rate of continuous cropping, and a high rate of declining soil fertility [1]. The majority of farmers in Africa employ or develop the fallow system to revitalize unfertile soil, however this method is no longer viable owing to the high levels of human population experienced around the globe as a result of rising population pressure [2].

The high rate of environmental pollution, mostly from phosphates and nitrates, has been caused by the rising expense of synthetic fertilizer and high degree of environmental degradation associated with its broad use. In particular in the developing nations, primarily in Africa, this has raised the amount of environmental and human health dangers. Therefore, a sustainable biofertilizer that may take the place of synthetic fertilizer has to be sought for. The level of the soil's biotic community has been impacted by the ongoing use of synthetic fertilizers, which has increased the amount of pesticide residue in some of these crops and, ultimately, weakened the agricultural system. There is a significant desire for nutrient-dense, higher-quality, safer foods that are also accessible in greater quantities[3]. This will significantly contribute to addressing the need of the continuously growing population. Additionally, there is a larger need to lower the excessive amount of synthetic fertilizer, particularly in Africa. As a result, there is a strong demand for food in the majority of these African nations, where there are still many areas where the population is densely populated and suffers from severe hunger. Due to this, sustainable agriculture and high levels of intensification are now necessary, and inorganic fertilizer must be replaced with eco-friendly fertilizer[4].

The use of several eco-friendly, cost-effective, and sustainable bio-inoculants, such arbuscular mycorrhizal fungi, has been the focus of increased study. Due to their environmental friendliness and potential to replace inorganic fertilizers, these helpful microorganisms have been identified as sustainable biotechnological solutions that could be applied as efficient soil fertility management techniques. Numerous studies have been conducted using arbuscular mycorrhizal fungi and rhizobial inoculants. The capacity of the bio inoculant to absorb nutrients for crops via diverse biological processes has been shown to include live cells of many different species of microorganisms. It has been shown that microbial inoculants are a formulation that contains helpful microorganisms that might actively contribute to the upkeep of the environment for sustainable agriculture. Microbial inoculants have been shown to be an environmentally benign alternative to synthetic fertilizers and insecticides. They include active microorganisms that might, either directly or indirectly, improve microbial activity by promoting nutrient transport in the soil. The newest information on manufacturing, marketing, and their ultimate use were examined. As a result, this chapter aims to give a thorough overview on the degree of biofertilizer production in Africa.

This section examined how biofertilizers are used to increase agricultural yield, environmental stress, their success stories, as well as their advantages and disadvantages in Sub-Saharan Africa, where there is limited information on their use on other continents. Low crop yield in Africa is a result of the continent's poor agricultural soil fertility and poor management. A sustainable kind of biofertilizer with little to no economic impact and little to no toxicity to agricultural soils is highly advised to help with these issues. The benefits that recent strains of microbes like Bacillus, Pseudomonas, Azospirillum, Azotobacter, and Rhizobium portend via growth-stimulating compounds, bio-control actions, nutrient solubilization, and biotic N2 fixation have been reported by the authors to play a crucial role in sustainable agriculture. The authors concluded by recommending the use of biofertilizer made from microorganisms as the most suitable and efficient soil enhancers for nutrient-deficient soil, ecosystem sustainability, increased food security, as well as poverty. They urge stakeholders and subsistence farmers to use this technique in order to potentially continue food production[5].

The crisis in Sub-Saharan Africa's food security and management. According to the authors, in order to satisfy people's fundamental nutritional needs, nourishing food, safe food, and food security must come first. There is an urgent need to increase soil nitrogen content because in the African continent, there are roughly 80% deficits, which may cause malnutrition and food insecurity. Additionally, an excessive N2 load in water may cause soil erosion, leaching, and eutrophication. However, there is a dearth of research that has been done to increase soil N2 for optimal food production and yield, as well as to improve the strength of adaptability to environmental stresses. The use of N2 in decreasing pollution was clearly examined in the study's gap with previous studies. They conclude by advising farmers and other important stakeholders to use N2-based biofertilizers as a tool for agricultural development and reducing ecological stress.

DISCUSSION

The possible use of azolla in the future as a biofertilizer to increase agricultural output. According to the scientists, the little leaf cavities of the Azolla plant are home to consortia of endosymbiotic organisms. Additionally, nitrogen-fixing bacteria, or cyanobacteria, play a significant role in agricultural concerns in the plant's cavities after it has been employed for field purposes. The authors also considered the potential difficulties and uses of Anabaena azollae as biofertilizer in Sub-Saharan Africa, where about 75% of the labor force depends on agriculture as one of the main economic engines, second only to crude oil. Additionally, the ecology of the plants was emphasized and described. It was also addressed if Anabaena azollae may be used to increase soil fertility and efficiency while minimizing the risks associated with its use in conjunction with chemical fertilizers. Worldwide, plant-based nutrients have provided significant, healthful byproducts to the teeming populations of African continents. In recent years, organic fertilizers have replaced chemical fertilizers as a means of increasing soil fertility and productivity. On the other hand, the effect on the food chain cannot be overstated[6].

In this context, a review will look at the role that biofertilizers might play in boosting soil fertility and agricultural productivity. According to the authors, biofertilizers have historically been used as a stand-in for soil fertility and crop productivity in the interest of sustainable agricultural practices. In order to control plant-soil deficits and abiotic stress, they claimed that the employment of beneficial microorganisms as prospective biofertilizers has become of the utmost importance in the agro-chemical industries. Bacteria, ecto- and end mycorrhizal fungi, cyanobacteria, phosphate-solubilizing micro-organisms/rhziobacteria, etc. are some of the microorganisms used for this purpose. The authors concluded that the optimum method for improving biotic/abiotic variables, plant development and growth, and nutrient and water absorption is biofertilizer.

Furthermore, biofertilizers are affordable, eco-friendly, and eco-sustainable, and they need to be suggested for improving the fertility and productivity of soil and crops. Biofertilizer is used in organic farming as a sustainable agricultural practice. NPK inorganic fertilizers have a reputation for boosting plant productivity. The harm to human health and the environment it heralds, however, cannot be overstated. Recent developments in agricultural technology have shown that biofertilizers have potential that can be tapped into, such as the capacity to increase the availability of nutrients to crops, the capacity to improve plant and soil tolerance to abiotic stress, and their non-toxic and environmentally friendly nature as opposed to the commonly used inorganic ones[7]. Furthermore, biofertilizer has great promise for long-term commercialization for growers, producers, and other industry participants. Inorganic fertilizers are increasingly being used by farmers in developing nations to improve soil quality and increase crop yields.

However, excessive use of it may promote soil acidification and pose a serious threat to groundwater, the climate, and food security via sustainable farming. An evaluation of biofertilizer's chances and potential as an alternative to inorganic fertilizers. According to the authors, biofertilizers are affordable, environmentally beneficial, and renewable. That biofertilizers may enhance nutrient absorption by soil and crops, hence enhancing agricultural yields and plant health. Due to their organic origin, biofertilizers do not have problems with alkalinity and salinity that cause soil erosion or leaching[8]. The authors concluded that since biofertilizers tend to promote stability in addition to by supplying nutrients and avoiding erosion and ground water contamination, they will help in the management and conservation of plants, animals, and soil quality.

The recent exponential increase in human population will have a negative impact on food security and safety. The prospective sustainable potential of using biofertilizers in plant growth and development is therefore explored in order to further close these gaps. The authors described how commercial chemical fertilizers are used extensively in contemporary farming practices to increase crop productivity. The harm to the environment and potential health risks throughout the food chain were underlined[9]. However, they said that the use of biofertilizers has been acknowledged as one of the finest substitutes for traditional fertilizers due to its ease of application and potential to promote plant development. It has long been recognized that microbes like cyanobacteria, fungus, and bacteria aid in the growth and development of plants. As a result, one of their many agricultural benefits is their ability to stimulate or provide nutrients in the soil that are necessary for plant life. It was addressed how to assess the use of bioremediation and ecology in sustainable agriculture.

Microorganisms are well recognized in agricultural ecology to have a significant influence in the structure and operation of the ecosystem. The efficiency and bioavailability of soil and crop soil nutrients are both improved by the whole microbial consortium. The use of chemical fertilizers to increase crop yields on farms has helped soil function and quality to some degree. But it has now been shown that persistent use adversely affects the structure and functionality of ecosystems. The authors described how using biofertilizers may increase plant adaptability, elicit nutrients competency in soil and crops, and help in the trace-ability of problems with inorganic consequences of agricultural inputs. They claimed that the Clostridium spp., Bacillus spp., Aspergillus spp., and Mycorrhizal spp. strains of fungi and bacteria help to improve PSB in the soil and the mutualistic association of soil-plant nutrient ratios, which have been major challenges in terms of mineralization and biomass for the Manihot esculenta plant.

According to the authors, this will help with managing climate susceptibilities and carbon impounding. A randomized full block design was used to assemble these media in triplicates. The study's findings demonstrated that Caesalpinia pulcherrima that had been placed in medium with biofertilizer grew more favorably than those that had received a control treatment. The plants infected with inorganic and organic fertilizers, respectively, grew more slowly than the Caesalpinia pulcherrima treated with a combination of biofertilizer with Muller solution and POME. Their study's conclusions suggested that using biofertilizers had a greater effect than using organic fertilizers. Between the POME conjugates and the Muller solution with the bio-fertilizer, there was tremendous development and growth. Better bacterial consortia were produced by using a mix of organic and biofertilizers than by using chemical fertilizer alone.

In order to control and enhance crops and soil nutrient deficits, the author concluded by recommending the use of biofertilizers. An overview of the advantages of using bacteria as biofertilizers. According to the authors, biofertilizers are latent microbial cell strains that have been prepared to help plants absorb nutrients, thrive, and engage in various ecological and biological interactions with the soil and one another. In order to sustain nutrient availability and absorption, biofertilizers also promote certain bacterial activities in the topsoil and within the soil. The usage of biofertilizers, according to the author's opinion, is particularly helpful in managing crop disease, ecological stress, and soil nutrient deficits since they include significant amounts of renewable nutrients that may complement inorganic ones and are inexpensive to acquire.

Different strategies have been used to control soil deficiencies and ecological stress in agricultural operations. Historically, inorganic fertilizers have been used to control soil, but it has been shown that their aftereffects are harmful to both ecosystems and plants. The important contribution of biofertilizers to sustainable farming in terms of improving crop output, ecological stress, and soil fertility is discussed in light of this. The authors said that due of their involvement in promoting environmental sustainability and food safety in the agricultural industry, biofertilizers are advised as a first-class fertilizer. In addition, the nutrient profile, crop productivity and growth, cellular response and pathways in crop improvement, and the effect of biofertilizers on these factors were examined in this research. In their conclusion, the authors expressed their opinion that by studying the physiology of biofertilizers, it would be possible to improve sustainable agriculture in Africa and lessen the negative effects of inorganic fertilizers.

In comparison to other continents, Africa uses a relatively little amount of biofertilizers. The likelihood of this is often predicated on ignorance of the potential benefits and applications in the agricultural sector, the lack of regulatory authorities to oversee the use's potential environmental effect, and knowledge in agricultural microbiology. According to the authors, use of high-value biofertilizers in Africa's agricultural sector would increase crop output, support plant growth and development, and promote nutrient absorption. In addition, they will reduce ecological stress factors and increase nutrient availability, bioavailability, and absorption. Some advantages of using biofertilizers, including their affordability, environmental friendliness, and non-toxic composition, were mentioned. The authors' conclusion underlined the need of raising awareness of the need to apply this technology to a sustainable food system in Sub-Saharan Africa.

The effectiveness and advantages of using AMF as biofertilizer. According to the authors, AMF are biotrophs that have an 80% plant colonization rate and are made up of consortia of obligatory microorganisms in the roots of higher plants. Due to their significance in photosynthesis, plant defense against parasites and diseases, nutritional bioavailability, and high water retention in plants, they may be employed as biofertilizers. AMF are the ideal replacement for conventional fertilizers. The genome of the AMF has been modified to adapt to green house, lab, and field use thanks to the application of transcriptomics and genomics in recent breakthroughs in biotechnology. The authors suggested that trials on AMF biofertilizer should concentrate more on critical elements that can facilitate or hinder the inoculation process in their conclusion.

Reviewing the difficulties with biofertilizer quality and formulation. According to the authors, the increasing demand for biofertilizers worldwide demonstrates their ineffectiveness and efficiency. However, they bemoaned the fact that recent discoveries of several contaminated versions in commercial markets had caused farmers to lose faith in their worth. In light of this, the best course of action is to create an inoculant using a variety of designed microbe strains that can endure challenging environmental conditions and increase nutrient absorption. The scientists also examined the numerous elements involved in creating biofertilizers with high nutritional value. Additionally, many methods were emphasized. A review of innovative biofertilizers' quality was also conducted. The authors concluded by suggesting that significant issues working against the innovative formulation be examined.

The quality of farm products has decreased as a result of repeated tilling of the land for agricultural purposes. The usage of conventional fertilizers has effects on the environment and human health as well. The overall production and health of the plant may be hampered by all of these elements or effects. The drawbacks and advantages of biofertilizers in agricultural practice were reviewed, however. The author said that while biofertilizers provide farmers and producers both financial and environmental advantages, there is a need to improve the quality of agricultural product using them. Additionally, they may improve the supply throughout the food value chain to the final customers as well as the safety of food. All things considered, they claimed that biofertilizers are affordable, environmentally benign, resilient to challenging biotic and abiotic environments, and non-toxic. The authors conclude by urging the use of this cutting-edge biotechnology to support sustainable agriculture.

CONCLUSION

This chapter has offered in-depth information on the use of biofertilizer for enhancing or increasing crop yield by raising the level of soil fertility. Discussions were held about the present state of bio-fertilizer use in Africa and their mode of operation. The introduction of several forms of biofertilizer was also emphasized. Additionally, there was a lot of discussion about particular instances when biofertilizer increased agricultural output. Therefore, it is necessary to identify and isolate a wide variety of advantageous microorganisms that may work as a biofertilizer and boost food production. Agricultural wastes must be used to mass produce these vital strains for the efficient manufacturing of biofertilizer.

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CHAPTER 20

FUTURE OPPORTUNITIES AND CHALLENGES FOR BIOFERTILIZERS

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ABSTRACT:

The microbial inoculant known as biofertilizer, which is an environmentally benign substitute for chemical fertilizer, preserves the lithosphere, improves the biosphere by preventing eutrophication, air, water, and soil pollution, and increases crop yields. By releasing plant growth regulators and enriching the soil with macro- and micronutrients, it also benefits plant development. Plants mostly need nitrogen, phosphorus, and potassium as nutrients. By secreting siderophores, antibiotics, enzymes, antifungal, and antibacterial chemicals as well as by releasing hormones and fending off illness and stress, the microbial inoculants of biofertilizers improve plant development and yields. N-fixing, phosphate solubilizing, phosphate mobilizing, potassium solubilizing, potassium mobilizing, and sulfur oxidizing biofertilizers are the different categories. With the introduction of "Nitragin" in 1895, biofertilizer had its first commercial outgrowth. Microbes must be mass-cultivated in order to create biofertilizer, while preserving the culture's pH, temperature, and cell count. An appropriate carrier material is needed for the biofertilizer to be delivered and function properly. As a sustainable option for agriculture, it should be prioritized in the future to develop mutant and genetically modified bacteria as biofertilizers that have better reaction than wild type.

KEYWORDS:

Biofertilizer, Bateria, Cyanobacteria, Carrier Material, Mycorhiza, N-fixers, P-solubilizers.

INTRODUCTION

The current situation is an increase in population, which is accompanied by a desire for healthier meals. The depletion of arable land, high input costs, scarcity of agricultural inputs, climatic variability, and loss of soil fertility all pose challenges to food production. Demand for healthy foods puts strain on agriculture's sustainability. The "green revolution" is crucial for the sustainable development of agriculture. It emphasizes on environmentally friendly methods to lessen the amount of damaging artifacts in the environment. The idea of "green technology" inspired academics to discover a new method for sustaining environmental usage without compromising its stability.

The use of environmentally friendly and biodegradable technology in tandem with nature in agriculture as an alternative to chemical fertilizers is one of the answers to this issue to preserve sustainability. An essential part of the lithosphere that both directly and indirectly sustains life is the soil. It is divided into three layers: the top layer, the parent layer, and the subsoil layer. The top layer, which comprises organic materials, air, water, and micro- and macro-inorganic nutrients, promotes the development of plants. To make soil fruitful, each component must be present in the proper ratio. Additionally, soil has microorganisms that contribute to its fertility and provide the nutrients that are present but not immediately used by plants. Due to the presence of microorganisms, the top layer of soil is engaged in the cycling of nutrients[1].An essential macronutrient for plants is nitrogen. It aids in the production of DNA and RNA, the heme of chlorophyll, cytokines, osmoregulation, and other processes. Nitrates, ammonium, and urea are the three main sources of nitrogen for plants. Inorganic matter breakdown, biological nitrogen fixation, thundering, and synthetic fertilizers are some of the ways it enters the soil. Another macronutrient that plants need in big quantities is phosphorus. It serves a variety of purposes, including promoting the development of legumes, increasing the number and mass of nodules, and acting as phospholipids in the membrane of the cell, and enhancing crop output and quality. Both nuts and fruits are reported to contain phosphorus, which is a necessary component. Phosphates are the form of phosphorus that plants may use. Fertilizers provide phosphorus to plants.

The second most important macronutrient for plants after nitrogen is potassium. It performs a variety of tasks, including as regulating stomata and transpiration, turgor maintenance, root development, and water absorption, which all contribute to plant production and growth. Additionally, it facilitates the synthesis, agglomeration, and catalysis of certain vitamins including riboflavin and thiamine. Potassium is essential for the effective operation of guard cells, for carrying out photosynthesis and protein synthesis, and for enhancing the quality of fruit. Additionally, potassium aids in boosting resistance to bacterial and fungal infections. Potassium ions are consumed by plants when they are released into the soil by decomposing organic waste and artificial fertilizers[2], [3].

Nutrients are highly important and are needed by the plants in both macro- and micro-quantities for their continued growth and production. The "Green Revolution"-developed high producing types need a constant supply of nutrients, irrigation water, insecticides, and pesticides. The monoculture method used to cultivate these cultivars year after year caused the soil to become acidic and to collect salts as a consequence of overwatering, leaching, and pollution of subsurface water and the atmosphere. The excessive and prolonged use of synthetic fertilizers weakens the roots of plants, making them more susceptible to disease. To address these issues and maintain agricultural output, an environmentally friendly solution is urgently required. This environmentally friendly alternative is a biofertilizer that is created utilizing helpful microorganisms.

One of the primary industries in the world is agriculture. According to estimates, one-third of employees are involved in agriculture, which produces an increasing amount of food grains to feed the world's expanding population. Synthetic fertilizers, irrigation, insecticides, and pesticides were major components of the 20th-century "Green Revolution." This has shown that the output of food grains has significantly improved, although it ultimately led to recession. The primary negative impact of the green revolution is the decline in food output in developing nations as a result of fertile soil. It is mostly brought on by fertilizers, which are widely employed to boost agricultural productivity in order to meet the demands of constantly expanding populations.

Chemical fertilizers have a number of negative environmental impacts, including soil infertility, genetic diversity loss, gas emissions like nitrous oxide, and chemical leaching. The soil fertility is also seriously threatened by industrial effluents including heavy metal pollution and petrochemical discharge. As a result, these issues need a different solution. These chemical fertilizers are very detrimental to both biotic and abiotic biosphere components. In addition to endangering humans and other living forms directly or indirectly, it contaminates the abiotic support system. Continuous usage of it disrupts the environment as a whole, making it difficult for living forms to survive.

DISCUSSION

Methamoglobinemia is a condition that causes the skin to become blue and damages the respiratory and circulatory systems. Consuming vegetables produced in soil that is high in NO3 also increases the risk of cancer. Excessive usage of a single chemical fertilizer might result in a lack of other vital substances; for instance, excessive K application causes a lack of ascorbic acid and plant carotene. When crops are produced using NO3 fertilizer, the amount of proteins in the crops decreases[4].

Farmers were driven to plant more and more crops from the same plot of land each year due to the demands of the expanding population. Farmers rely on chemical fertilizers to keep up with the demands of an ever-increasing population, but this has led to eutrophication, soil acidity, and soil barrenness, as well as the weakening of plant root systems. With the employment of soil microbes and organic fractions as biofertilizers, this has accelerated the transition from stereotypical conventional farming toward eco-friendly organic agri-culture. These biofertilizers are nutrient-rich and provide several benefits over chemical fertilizers, including increased soil biodiversity, economic effectiveness, and food safety.

Nowadays, a variety of microorganisms are employed as an alternative to chemical fertilizers. Microbes may be used as an alternative to chemical fertilizers to improve plant development in a number of ways, including by fixing nitrogen, solubilizing and mobilizing phosphates, zinc, and potassium, and by releasing plant growth regulators. Additionally, biofertilizers assist plants in surviving under adverse conditions. The fact that these microorganisms have the capacity to promote growth and have been used in agriculture since the 1950s has earned them the nickname "plant growth-promoting bacteria." Its widespread commercial use has been impeded by several of its drawbacks, including vitality, efficiency, adaptability, and inconsistency.

Since then, several strategies have been used to enhance and get around these limitations. Industrial effluents, which also include heavy metal pollution and petro-chemical discharge and may be remedied by the use of biofertilizers, pose a significant hazard to soil in addition to chemical fertilizers. By reversing their negative effects, the organisms utilized in biofertilizer have the ability to combat metal stress. By fixing nitrogen, solubilizing phosphate, releasing bound potassium, secreting chemicals that promote plant development, making antibiotics, and mineralizing soil's inorganic and organic materials, these bacteria replenish the soil with macro- and micronutrients. The use of biofertilizer is a long-lasting, environmentally responsible option that increases the flavor, taste, and scent of the final product, prevents eutrophication, and reduces soil acidity without lowering fertility. It aids in the management of plant diseases such parasitic nematodes, chilli fusarium wilt, pythium-induced root rot, and rhizoctonia-induced root rot. It improves the water retention capacity and aids in tying soil particles together to stop soil loss from erosion and desertification.

Biofertilizers are described as compounds that act as microbial inoculants and promote plant development while preserving the environment's sustainability. The physiologically active bacterial and fungal strains that make up biofertilizers assist to grow, add, preserve, and convert nutrients from an inedible state to a useable one. By introducing advantageous bacteria and fungus to the soil, biodiversity is increased. Microorganisms like symbiotically linked arbuscular mycorrhiza fungus, nitrogen-fixing organisms, phosphate-solubilizing organisms, and soil organic matter decomposers are examples of biofertilizers. By releasing chemicals that encourage plant growth and development as well as antibiotics to defend against dangerous microorganisms, they increase yields. Biofertilizer is the foundation of integrated nutrient management since it contributes to the nutrient cycle and maintains a sustainable and healthy ecosystem. Biofertilizers have been shown to boost plants' ability to respond to stressful situations, which is important since crop survival and grain production are dependent on environmental factors like biotic and abiotic factors.

Auxiliary Bacteria

Some bacteria may be categorized as biofertilizers even if they do not fall into any of the existing categories. These bacteria increase plant development by acting as a third party to the plant-microbe relationship. For instance, isolated rhizospheric actinomycetes from legumes and actinorhizal nitrogen-fixing nodules promote nodulation, which aids in nitrogen fixation and ultimately leads to plant development. Although this kind of tripartite interaction is still not fully understood, it has been shown that it may increase the effectiveness of biofertilizers.

New Biofertilizer Technologies

Due to the presence of nitrogen-fixing microbial inoculants, biofertilizers restore the fertility and productivity of soil. Leguminous plants' root nodules contain rhizobium, which has long been used as a biofertilizer. Azotobacter is furthermore used for promoting development. Another promising microorganism for use as biofertilizer is Azospirillum. Other creatures include blue-green algae, which are often used as biofertilizer. By enriching the soil minerals via the breakdown of organic leftovers and agricultural byproducts, compost manufacturing boosts crop output, demonstrating the effectiveness and environmental friendliness of biofertilizers. The introduction of "Nitragin" by Nobbe and Hilther in 1895 marked the beginning of the first widespread commercial use of biofertilizer. Azotobacter and blue-green algae were also used as biofertilizer.

Azospirillum usage as biofertilizer is a relatively new phenomena. While the new addition in terms of biofertilizer is the vesicular-arbuscular micorrhizal roots. Rhizobium manufacturing for commercial purposes initially began in 1956. Malaysia was the first country to employ Brady rhizobium as inoculants in leguminous plants. Halim at University Putra Malaysia investigated the role of nitrogen from Azospirillum and Mycorrhiza in oil palm seedlings. Since then, several studies have been conducted, and various microbes have been suggested for use as powerful biofertilizers. Along with Azotobacter chroococcum, several Rhizobium species are used as nitrogen fixers in biofertilizers[5]. Some cyanobacteria that fix nitrogen are also effective biofertilizers used in agriculture. One example of a microbe that enriches phosphorus is Bacillus megaterium. Additionally, fungi like Aspergillus fumigates may fix phosphorus. Rhizobacteria, which promotes plant development, has also been shown to solubilize phosphorus when combined with vesicular

Making of Biofertilizer

The application of biofertilizers improves the growth and productivity of crop plants by increasing the amount of nutrients available through the decomposition of organic matter, fixation of atmospheric nitrogen, mineralization of salts, and solubilization of bound phosphorus. These particular and chosen microbe strains are produced in the lab on a big scale and combined with the appropriate carrier to create biofertilizers. In liquid form, biofertilizer is also used in conjunction with microorganisms and their nutrients to protect cells, promote cyst development, and resting spores from harmful environmental factors. Along with organic manures, current biofertilizers include microorganisms that are good for the plants and maintain environmental sustainability.

Making and using biofertilizers is environmentally benign and economical since they utilise soil and plant bacteria that are already present. Auxin, cytokinin, gibberellic acid, and ethylene are just a few of the growth hormones that biofertilizer bacteria encourage plants to produce. These hormones are important for both general and reproductive development as well as increased productivity. In this context, particular focus is placed on rhizobacteria that have strong potential to promote plant development. Numerous they are directly engaged in the mobilization and solubilization of phosphate, potassium, sulfur, and iron as well as the fixing of nitrogen. By eliminating the pathogens by the secretion of siderophores, antibiotics, enzymes, or fungicides, they indirectly aid in plant development. The microbes of biofertilizers can increase plant growth and productivity in one of three ways: indirectly by suppressing plant disease serves as bioprotectant, by promoting plant growth by improving nutrient absorption function as biofertilizers, or by secreting phytohormones known as biostimulants[6].

System for Making Biofertilizer

There are several factors to take into account while creating biofertilizer, including microbial properties, application techniques, and storage. The creation of biofertilizer involves six processes. These include selecting an active microbe, choosing a propagation strategy, picking a target microorganism, Picking a carrier material, choosing phenotypic testing, and Wide-ranging tests. The selection and kinds of microorganisms to be utilized as a single organism or combinations of incubators are the first steps in the creation of biofertilizer. The selected bacterium is then cultured in the laboratory as the following stage. The carrier material must then be chosen. The carrier material is chosen based on the biofertilizer's requirements. For example, if a powder form of the biofertilizer is required, peat or apioca flour should be used as the carrier material. The choice of propagation technique comes next. The microorganism's growth characteristics determine the propagation process. Last but not least, biofertilizer is evaluated in a variety of environmental settings to determine its limitations and possibilities. 500–800 g of biofertilizer are combined with 10-15 kg of farmyard manure before being applied to the soil. Before being added to the soil as a useful biofertilizer for plants, the contents are well mixed and preserved. This phase is crucial because organic manure is necessary for the development and functioning of biofertilizer.

Mechanism of Biofertilizers' Growth-Promoting Activity

Different microorganisms use various strategies to encourage plant development. For instance, Azospirillum secretes auxins, gibberellins, and ethylene to promote plant development. Additionally, it produces certain antibiotics that aid in the management of plant diseases. It also creates vitamin B complex in addition to these. Some bacteria stimulate the production of phytohormones, such as Paenibacillus polymyxa, which causes IAA to be produced in the roots of lodge pole pine. IAA complex is synthesized by Bacillus and Rhizobium as well. IAA and gibberllic acid are produced by phototropic prokaryotic microorganisms. Additionally, it enriches the soil with vitamin B12, which increases its potential for complex water binding and aeration. Azolla brasiliense Nitric oxide is produced by Sp245 to promote tomato root development when combined with IAA. The production of IAA, which aids in root development, uses nitric oxide as an intermediary. Regardless of the method a biofertilizer employs, it must penetrate the rhizosphere and show its effects on plants via the interaction of roots. The biochemical and genetic composition of the utilized microorganisms, as well as their actions, are used to categorize the growth-promoting properties of biofertilizer into two modes of action. The following is a description of the two ways that biofertilizer works: I. direct: when biofertilizer supplies nutrients or growth stimulants to boost plant development; and indirect: when biofertilizer prevents or removes the unfavorable conditions that affect plant growth[7].

Along with improving development characteristics, biofertilizers aid plants in their ability to withstand a variety of stressors. To combat salt stress If Trifolium alexandrium is coninoculated with Rhizobium trifoli, the result will be favorable. This particular mix of microbes also shown an acceptable biomass nodule number. Pseudomonas aeruginosa has shown success in handling diverse biotic and abiotic stress. Pseudomonas putida RS-198 improved the rate of germination of the cotton plant. Additionally, it assisted in boosting cotton's growth indicators like weight and height. It improves these characteristics under high-salt conditions by increasing the intake of ions such as Ca2+, Mg2+, and K+ and by slowing down the consumption of Na+. Some Pseudomonas strains use the compound 2, 4-diacetylphloroglucinol to assist plants in becoming more tolerant. Mycobacterium phlei also shown useful findings for surviving in conditions of high salinity and temperature. In cases when the environment is heavy in salt, AMF may also produce presentable plant growth. Piriformospora indica is only one of several microorganisms that are beneficial biofertilizers for salinity environments. Combining bacteria that fix nitrogen with fungi like arbuscular fungus may assist legume crops survive conditions of water shortage. Pseudomonas spp. was shown to be satisfactory for seedling development and seed germination in drought-like conditions. Arbuscular mycorrhiza may have an advantageous effect on photosynthetic capacity and antioxidant properties. By treating the banana plant with Bacillus subtillis N11 when compost is introduced, Fusarium infection may be managed. Cadaverine, a substance produced by Azospirillum spp., helps rice seedlings withstand osmotic stress.

Benefits and Drawbacks

By decreasing the pollution of the air, water, and soil brought on by chemical fertilizers, biofertilizers have a huge potential to preserve the sustainability of the environment. It improves soil fertility and microbial variety, supports plant survival under varied stresses, and controls plant disease. However, some biofertilizer drawbacks prevented their widespread use and implementation on a commercial basis. The major constraints in the industrial scale production are the supply of lower-nutrient content compared to chemical fertilizer, variation, or deviation of its efficacy on storage and external conditions of light, temperature, and humidity, inappropriate microbial strains, inappropriate carrier materials, lack of quality assurance, unskilled and inefficient staffs, low volume production, and flawed inoculation techniques, mutations of the strains, and market availability.

Future Potential

Biofertilizers are the ideal alternative and solution to the many current issues with the contemporary production system since they are environmentally benign, and they may be beneficial for the sustainability of agriculture. It has ushered in a new era in the production of field grains with the possibility of a second green revolution, despite several constraints linked to its production, consumption, applications, and commercialization. 90% of symbiotic associations with plants include AMF, however these organisms are still not culturable in a lab setting. A lot of research and development is required to find a good culturable approach for this fungus' growth in lab-oratory because of its significance for soil conservation agriculture management. A little progress in this approach with a chance of growing it in the carrot root organ may be a great start.

Many additional microbes' potential for usage as biofertilizers has not yet been fully investigated. Therefore, if the goal is to preserve agriculture in the future, the hunt for such helpful microorganisms will always be in need. The usage of biofertilizer has several restrictions since it may be impacted by soil native bacteria and environmental factors. In order to receive the best response from biofertilizer in all environmental circumstances and soil types, the attention should be shifted to overcoming these constraints in the future. Azospirillum, which aids in enhancing plant growth by fixing nitrogen, was subsequently discovered to do so by proving its impact on root architecture and development. Later research demonstrated that Azospirillum glutamine synthetase mutants produce more growth than the parental type. In a similar manner, many more mutants may be created, examined, and evaluated against parental kinds in the future to get outcomes that are superior to those of wild-type bacteria. Searching for further triangular partnerships to improve the efficiency of biofertilizers.

Not all natural microorganisms include certain enzymes that are directly related to the growth and development of plants. For instance, 1-aminocyclopropane-1-carboxylate deaminase, which is involved in the removal of ethylene, stimulates the development and production of plants. This enzyme's gene was discovered, extracted from Pseudomonas putida, and then transferred into other bacteria to transform them into PGPB. Therefore, in order to create genetically modified plant growth-promoting microorganisms in the near future, we need look for such genes and use biotechnology techniques. This will undoubtedly provide a fresh route to unstoppable agricultural development[8].

CONCLUSION

Fertilizers are used to help feed the growing population since the population is growing. Due to the use of chemical fertilizers in response to the "Green Revolution," the output of food grains has increased. Chemical fertilizers are crucial for increasing agricultural productivity and output, which has led to a sharp rise in their demand. But as time went on, it was discovered that chemical fertilizers had a number of drawbacks, including the contamination of air, water, and soil, infestations of plant diseases, and the creation of new pests, which ultimately lowers the productivity of the same plot of arable land. These elements have turned into a challenge for the long-term viability of agriculture. Because of these issues, biofertilizer development has become essential in order to sustainably increase agricultural output. As microbial inoculants, biofertilizers provide numerous benefits without these downsides. These bacteria assist roots in properly using soil constituents that are often unavailable to plants. These microorganisms in biofertilizers release hormones into the soil that aid in plant development. Therefore, biofertilizer is a possible technology that uses sustainable inputs to boost soil fertility using microorganisms that assist agricultural productivity by adding organic nutrients to the soil. Because they are bio-inoculants, environmental factors also affect how biofertilizer reacts. The function of biofertilizers is influenced by the kind of soil, nature of the soil, native microbial content, composition of the soil, etc. To advance biofertilizer technology, it is crucial to thoroughly understand the ecology and dynamics of soil microbes in addition to external and internal elements. When combined with other microbial strains, a single microbial strain uses a unique method to improve plant growth and production, and this mechanism's dynamic changes. As a result, it is highly challenging to determine the precise mechanism through which biofertilizer stimulates plant growth and overall yields. Future biofertilizer formulations may be made considerably better with the use of biotechnological technologies and genetic and molecular biology expertise. The wide acceptance and use of biofertilizers as a sustainable alternative to the current agriculture production system would undoubtedly be improved by the development of new technologies for efficient production systems with beneficial and modified microbes, better handling systems, and enhanced storage shelf-life. Consequently, there are a ton of opportunities for new businesses in the biofertilizer sector.

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CHAPTER 21

THE HISTORY, PRESENT AND FUTURE OF BIOFERTILIZERS

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ABSTRACT:

The demand for food and other agricultural products has increased in tandem with the global population's ongoing growth. In order to achieve high yields, this has also led to the development of new agritechnologies, which has dramatically expanded the use of chemical fertilizers. Chemical fertilizers, which primarily include N, P, and K, are manufactured in industrial settings on a large scale. Chronic use of chemical fertilizers not only degrades soil fertility but also adversely affects human health when they enter the food chain. They also have a negative impact on crop productivity and render the soil infertile. The approach to sustainable farming has been strongly requested as a result of these challenges. By using biofertilizers, which protect the soil environment via a variety of processes such as nitrogen fixation, potassium and phosphate solubilization, and the breakdown of organic matter in the soil, sustainable farming may be accomplished. Although they seem to be a favorable alternative, detriments are also present in biofertilizers. Future efforts will primarily focus on enhancing biofertilizer performance and lowering production costs to address environmental issues in the most effective and cost-effective manner possible. For this, more recent methods are presently being developed, such as coating, co-encapsulation, fermentation, lyophilization, and inoculation. Future agricultural practices that are both environmentally benign and economically feasible will benefit greatly from the development of fertilizers employing chemical, organic, and microbiological sources.

KEYWORDS:

Biofertilizer, Chemical Fertilizer, Sustainable Farming, Nitrogen Fixation, Inoculation.

INTRODUCTION

The demand for food and agricultural goods is rising at an alarming pace throughout the world along with population growth. Due to their reputation for boosting production, chemical fertilizers are now both necessary and dependent upon due to the rise in demand. Pesticides play a vital part in the production of food and its high yield in addition to chemical fertilizers. In an industrial context, chemical fertilizers are created and manufactured. These are principally made up of N, P, and K in the specified proportions. The constant use of these resources increases productivity and yield on the one hand, but it also poses a serious threat to environmental issues such as soil, groundwater, and surface water quality degradation, air pollution, decreased biodiversity, and ecosystem collapse[1]. Additionally, it harms aquatic ecosystems and eats up scarce phosphorus supplies, pollutes groundwater with nitrates, and fosters mistreatment and overuse of those resources.

This has made it necessary to channel and fiercely concentrate efforts to manufacture high quality, nutrient-rich food products in order to achieve sustainable ways of securing the eco system via the adoption of bio-safety procedures. This demand highlights the need for bioorganic fertilizers since they provide an alternative to fertilizers that are chemically based and agrochemicals[2]. These biofertilizers work thanks to microorganisms that are good for the soil and encourage plant development. Such microorganisms are in great demand for sustainable farming because they enable safe crop production and prevent environmental damage. These advantageous microorganisms are often referred to as biological pest control or biofertilizer agents. By fostering a symbiotic relationship with plants, biofertilizers keep the soil environment rich in all kinds of nutrients[3]. This is accomplished by releasing compounds that control plant development, decomposing organic materials, fixing nitrogen, mineralizing phosphate and potassium, and producing antibiotics. By using biofertilizers, the nutritious components that aren't useful may be mobilized into useable form. Biofertilizers have gained increased significance over the last two decades and are now a key component of an integrated strategy to nutrient management. Typically, 10% to 40% of the fertilizer provided to a plant is absorbed, whereas 60% to 90% is wasted. Microbe inoculants are especially important in these circumstances because they take an integrated approach to managing nutrients for safe environments and sustained output[4]. Because they assist in the nutritional maintenance cycle of the crop or plant and proliferate when employed as an inoculant of soil or seed, biofertilizers considerably increase agricultural production. These days, its common practice to utilize microorganisms that are advantageous to plants since they help crops meet their nutritional needs while also enhancing and maintaining fertility throughout time.

In addition to knowledge on microorganisms and plant physiology, technical issues such as the fermentation process, formulation type, type of microbial population, and their release method have a significant impact on the manufacture of biofertilizers. Because biofertilizers are accepted by the ecosystem and provide a substantial contribution to contemporary agricultural technology, it is obvious that a combined understanding of technological and microbiological issues must be used when creating a bio formulation that can be stable. In-depth research has recently been done on how soil and other types of microbes interact with plants[5].

Although this research provide light on the interactions between plants, soil, and different types of microorganisms and investigate methods for their use in agriculture, their broader application is limited by variables including technology, inoculate mimicry, and inoculate carrier. The features and characteristics of formulations, such as encapsulated formulations, polymeric formulations, inorganic, organic, culture production, techniques of inoculation, bulk sterilization, and techniques of seed coating, need to be extensively explored in order to fully understand the utility of microorganisms in agriculture in the form of biological fertilizers[6]. This chapter gives a broad review of biofertilizers' historical development, present technical state, and prospective future in terms of fresh methods for boosting nutritional profiles, reducing environmental stress, and bacterial inoculations.

Additionally, microbial inoculums have a history of use in crops, and their expertise has been handed down through the centuries. It all began with the small-scale production of compost cultures, which gave an understanding of the possibilities of biofertilizers. In Malaysia, industrial-scale manufacturing of microbial inoculants began in the late 1940s and progressively increased until the 1970s. The MRB, a government research institute, advanced a study on Rhizobium inoculums for leguminous crops[7]. Mycorrhiza research was pushed by University Putra Malaysia in the 1980s. The goal of the research was to determine how much nitrogen Azospirillum contributed to palm oil seedlings. The development of biofertilizers as inoculants and carriers of microorganisms is a result of advances in the study on these fertilizers.

Classification of Biofertilizers

Biofertilizers often differ from frequently used chemical fertilizers in that they include intentionally maintained cultures of soil microorganisms. Since they include microorganisms that make nutrients more accessible to plants, biofertilizers may be employed as inoculants of soil or microbes that are introduced to improve soil fertility and plant production. The extract from plant products has several uses, including preventing corrosion for future use in the agriculture business and agriresearch as they replace hazardous and poisonous chemical-based inhibitors. Examples of microorganisms employed as biofertilizers include bacteria, fungus, and blue-green algae. To increase soil activity, these microorganisms are given to the plant rhizosphere. Biofertilizers may be categorized as follows based on the purpose and makeup of the microorganisms.

Nitrogen fixers are the organisms that fix atmospheric nitrogen by turning airborne nitrogen molecules into similar nitrogen-containing compounds in the soil, such as ammonia. Thus, a process known as biological nitrogen fixation transforms atmospheric nitrogen into nitrogenous molecules that plants may use[8]. These are further divided into nitrogen-fixing bacteria that are symbiotic and those that are not. Rhizobiaceae family microorganisms such as Rhizobium, Azorhizobium, Bradyrhyzobium, Mesorhizobium, and Sinorhizobium, which are collectively known as rhizobia, are examples of symbiotic nitrogen-fixing bacteria. Leguminosae plants and non-leguminous trees have a symbiotic interaction with rhizobia. Cyanobacteria, Azotobacter, Azospirillum, Diazotrophicus, and Gluconaacetobacter are some non-symbiotic examples of nitrogen-fixing bacteria. The non-symbiotic kinds may be found as endophytes, free-living organisms, or in associative forms.

Many microbial species have the ability to solubilize phosphorus, making them useful as phosphorus-solubilizing biofertilizers. These include, to some degree, algae, fungus, bacteria, and actinomycetes. Arthrobacter, Bacillus, Chryseobacterium, Gordonia, Pseudomonas, Rhodococcus, Serratia, and other bacteria are examples of microorganisms. There have been reports of fungus such as Aspergillus, Penicillium, Trichoderma strains, and Rhizoctonia solani strains solubilizing phosphorus. The microorganisms known as phosphorus mobilizing biofertilizers promote and improve phosphorus absorption. These work together in a symbiotic relationship based on the exchange of nutrients between soil fungus and plant roots. Through the process of photosynthesis, plants create sugar and provide it to fungus. The network of fungi's hyphae improves the plant's ability to absorb nutrients and water. Arbuscular mycorrhizae, also known as endomycorrhizae, are included in the example.

Microorganisms with the ability to dissolve silicate, such as rhizobacteria that can dissolve silicate, are considered biofertilizers as micronutrients. So that silicon and potassium are easily accessible for crops, the silicate-solubilizing rhizobacteria enhance silicate mineral solubilization. Rhizobacteria that Promote Plant Growth: Rhizobacteria that Promote Plant Growth are those bacteria that are found in and around the rhizosphere. These are also known as plant growth-promoting bacteria, or PGPB, since they are capable of boosting plant development. These include species of Bacillus and Pseudomonas, which either suppress plant disease, facilitate nutrient absorption, or function as biostimulants for the production of phytochromes.

Different Biofertilizer Paradigms

Fertilizer impregnation and fertilizer use effectiveness

The effectiveness of fertilizer application is a crucial indicator for assessing how fertilizer management and the interaction between soil, water, and plants affect crop output. FUE denotes the likelihood of nutrient loss in the environment from the current agricultural systems and further provides the path to fill the gap since agrimanagers are primarily focused on meeting the continuously expanding food demand of society. It should be remembered that FUE measurements are not indicators of nutrient loss since soil holds onto nutrients. As a result, low FUE may not necessarily be harmful to the environment, and high FUE values do not indicate environmental safety. Mineral fertilizers must be used often in agriculture due to their uses, and their impact on crop production may be predicted based on the FUE of crops. The loss of mineral fertilizers is a result of processes such soil erosion, leaching, and denitrification, which not only hurts the economy but also harms the ecology[9]. There is a significant need for the usage of bacteria that stimulate plant development since the use efficiency of fertilizers containing nitrogen and phosphorus is low, and these bacteria have a progressive influence on the environment and plant growth. As a unique strategy to improve plant nutrient usage efficiency, bacteria-impregnated fertilizers are currently being developed. Plant growth-promoting bacteria impregnation with mineral fertilizers is a revolutionary idea and sophisticated strategic technique to boost plant growth and crop output when compared to previous methods.

The coating of chemical fertilizers with various mineral kinds and plants with bacteria that support plant development is known as impregnation of fertilizers with bacteria. This is done to increase the amount of beneficial microorganisms in the rhizosphere and the effectiveness of the fertilizers used. It is anticipated that fertilizer impregnation, or the coating of chemical fertilizers with microbes, would start the adoption of dietary sources and maybe improve understanding of FUE boosted by bacteria.

Mixtures of bacteria used as Inoculants

The use of mixed inoculants, rather than employing individual microorganisms, is crucial since it increases the crop's potential because the various microorganisms' differing modes of action are combined in the inoculum. The use of inoculants containing microbial mixes coupled with species that fix nitrogen, dissolve phosphorus, and mobilize potassium seems to provide a substantial option in this regard. Research on inoculants of mixtures of microorganisms has also shown that they prove to be useful to a greater degree than utilizing inoculants of single microorganisms when diverse microorganisms with varied advantages are put together. Common biofertilizers may provide prospective and promising output in a desired and creative way by adding various bacteria with various skills. Because microbial mixtures provide a broad range of impacts and greater effectiveness, it is crucial for plant development and soil strength to continuously investigate effective strains of microorganisms that are favorable for crops.

Different Inoculant Formulations

An effective strain's inoculation development consists of a microorganism, a carrier, and an additive. A bioinoculant's formulation often comes in liquid and solid form, which presents challenges due to limited microbial viability during storage and administration. Since there are several factors that together have an impact on microbial cell viability, bacteria need formulations that are more protective and that also increase their effectiveness at the target location. The effectiveness of the inoculant is the key criterion for commercialization since its poor quality and inappropriate formulation severely limit its widespread acceptance and use. A significant obstacle to commercialization is the way in which flora and animals interact with vaccines. Therefore, for widespread usage, the inoculation formulations need to demonstrate stability throughout manufacture, supply, transit, and storage.

When creating formulations, the agricultural environment should be taken into account. This includes droughts, high temperatures, acidic soils, saline soils, and soil erosion. Utilizing indigenous strains of plant growth-promoting bacteria that are resistant to any kind of physical or chemical stress would be a helpful strategy in such situations. The process of creating an inoculant formulation must be based on the fundamental principles of microbiology, material science, and plant biochemistry. Applying the information from these fields makes it easier to create ecological and agricultural solutions that are sustainable. The creation of an appropriate formulation necessitates ongoing study in the formulation sciences since an acceptable formulation is never easy to create and has only had sporadic success in the commercialization of bio-inoculants. A strategy for formulation creation is mostly dependent on a number of variables, including equipment availability, farmer convenience, plant intrinsic traits, application technology, and location of action, cost, application method, and inoculant colony.

Immunization Carrier

The formulation of microbial fertilizers has to be sustainable in order for plants to be exposed to them over an extended period of time. Effective application depends on the technique being used to produce carrier formulation and inoculum at its best. The final inoculant product will always be in the form of powder, granules, slurry, and liquid and may be applied to seedlings, leaves of the plant, compost, seed, and soil. However, there may be major differences in the carrier raw material and the kind of formulation. The inoculant carrier must be abundantly found in nature, sterile, as physically and chemically homogenous as feasible, capable of storing water, and suitable for various bacterial strains.

The employment of coating technology to assimilate the microorganisms employed in biofertilizers may be utilized as a method to lower the total cost and volume of fertilizers, increasing farmers' profits. The most affordable coating material and inoculant carrier are the need of the hour for current and future research on bio-organic chemical fertilizers, and sustainable agriculture may be accomplished by combining microorganisms with improved coating technologies. It has been shown that delivering biofertilizers to the intended locations on a suitable media may increase their biological activity. The water-in-oil emulsion formulations are also employed for storage and subsequent application to crops employing irrigation systems. The suitable carriers widely used in bacterial formulations include mica, lignite, mud filter, talc, perlite, zeolite, vermiculite, bentonite, saponites, coal, inorganic soil, saw-dust, wheat bran, rice bran, husk of rice, manure from poultry, waste from banana, mineral and vegetable oils, and polymers like polyacrylamide, alginate, carrageenan, kaolin, alginate-kaolin, silicates, cellulose gels and powder formulations, clays, liquids, and peats . While solid formulations need charcoal, bentonite, lignite, and peat, powder and granular formulations need media like saponites, mica, wood pulp, lays, polysaccharides made of seaweed extracts, gums, alginates, starches, plant extracts, and microbial gums. For seed coverings, formulations in granular and powdered solid forms are needed.

Liquid formulations and Biofertilizer Carriers

Currently, liquid biofertilizers are seen to be the greatest alternative when compared to biofertilizers that need a carrier as a medium. The liquid carriers used in biofertilizer formulations, such as oil, water, solvents, suspensions, and emulsions, are the most common. Concentrates, suspensions, and emulsions are all examples of liquid formulations. The major methods used to create liquid inoculants include oils, emulsions, and suspensions made from mineral or organic oils. Emulsions are largely utilized for the transport and storage of microorganisms via liquid formulation. Microorganisms are often delivered and stored via the emulsion in liquid forms. Sugars like sucrose and mannitol, water, and other chemical nutrients are needed in liquid formulations as a substrate for plant development. The most suitable biofertilizers for this are those in liquid form since they guarantee long-term organism life and provide a suitable environment for the crop. Therefore, it is essential to establish methods and advancements for appropriate carrier development and formulation technology refinement. In comparison to other biofertilizers, which are primarily based on carrier-based media, liquid biofertilizers provide ease in application. Increased plant output, reclaiming healthy soil, and production of sustainable food are all made possible by liquid biofertilizers.

Techniques for Controlled Release: Drying, Lyophilization, and Encapsulation

In terms of delivery to the target location, the typical technologies utilized to apply active chemicals to the plant lack selectivity. Thus, controlled release systems are needed for the controlled release of active ingredients to promote plant development and further limit active ingredient loss that may result from local climatic and soil circumstances. Lyophilization and encapsulation are the two most effective methods for controlled release systems. The encapsulation technique involves covering the microbe with a coating to protect it. Immobilization of microorganisms lengthens the shelf life of nutrients and improves field productivity. For regulated release into soil, encapsulation is necessary since this may release inoculants of microorganisms with diverse compositions and morphologies. By forming a protective shell or capsular covering over the cells, tissues, or active plant ingredients, the sophisticated method of microencapsulation improves nutritional shelf life and application efficiency. For instance, bioencapsulation of rhizobium bacteria protects soil microbes and allows for a gradual, protracted release. The use of seed and soil in the form of microencapsulation is superior to other formulations because it increases bacterial survival and has a longer-lasting impact.

Bacteria are protected by microencapsulation from unfavorable environmental factors. According to reports, problems associated with liquid and dry inoculants may be resolved by encapsulating freeze-dried bacteria in dried alginate beads. This is because bacteria in encapsulated form are dry, readily biodegradable, and convenient to handle, and they allow for a slow release of germs over an extended period of time. Alginate and kaolin are often combined to create beads, which are subsequently lyophilized. Clay, polymers of natural and synthetic origin, carbohydrates, proteins, starches, polystyrene, polyurethane, and polyacrylamides are some of the materials that are often used to bioencapsulate bacteria. Although there are benefits, the primary drawbacks of the microencapsulation approach include the need for specialized equipment for spray drying, the orderly stages for good encapsulation, the length of time required for encapsulation, and the expense of the encapsulation substance. The microbial drying procedure, which has a low cost of storage and distribution and is more susceptible to contamination, may accomplish long-term protection and preservation. The most popular techniques for drying microorganisms for use in biofertilizers are lyophilization, spray drying, vacuum drying, air drying, fluid bed drying, and freeze drying.

Biofertilizers: State of the Art

In order to increase the stability of biofertilizer and further extend its efficiency and longevity in the natural soil circumstances, current research efforts have recommended developing fertilizer employing various types of metabolites, microbes, and inert materials. Bacteria-impregnated fertilizers are essential because they boost the amount of helpful microorganisms and fertilizer effectiveness. Along with biofilms, which are also used to create plant inoculum, the utilization of compost enriched with microorganisms is becoming more and more significant in recent years. Agroindustrial waste includes microorganisms and rock phosphates. Utilizing this waste may reduce production costs and improve the efficacy of nutrient utilization. To further assist the creation of biofertilizers, carriers such as biofilm-based carriers, polymer-based carriers, natural carriers, macrocapsules, and silica gel encapsulation are being developed. According to research, bacteria may adhere to silica membranes covered with alginate micrograins. Recently, highly technical and financially viable models have been put out for the concept-based design of liquid biofertilizer manufacturing facilities. This is intended to further pave the path and inspire agricultural researchers and engineers in their analysis, optimization, creation, and assessment of novel biofertilizer manufacturing techniques.

Information on plant interactions has to be gathered prospectively. This makes it easier for many kinds of organisms to improve plant development and their potential value as biofertilizers. It is clear that microbial fertilizers may be effective if local strains are chosen and applied to the intended crops. When several microorganisms with distinct advantages can be incorporated into the crop plant, the inoculum made up of various bacterial combinations is very valuable. It is necessary to include several microorganisms into one product in order to promote a variety of additional benefits. The use of microorganisms in agricultural activities may be enhanced. Local strains, coating materials, and excellent protectants may be employed in this case to save manufacturing costs and provide an appropriate carrier. The creation of carriers, methods for encapsulation, and novel technologies that extend the shelf life of biofertilizer are all essential for their use and applications in the manufacture of biofertilizer.

Thus, the approach of coating bacteria may be utilized in addition to already establish carrier-based or bio encapsulation techniques, increasing the effectiveness of formulations of microbial mixtures and chemical fertilizers. The development of inoculant formulations based on the concepts of plant biochemistry, plant pathology, and plant microbiology will be crucial for sustainable agriculture and the search for long-term environmental solutions. Since it might be difficult to find strains that are effective, local strains can be employed since they perform well in all agricultural settings. Therefore, integrating organisms with one another and with plants may provide very advantageous outcomes. Since the effectiveness of inoculation varies depending on a number of factors, including but not limited to different plant species, soil types, and climatic conditions, a method has been developed to identify and match inoculants.

Exploiting potentially advantageous plant strains requires not only improvements in formulations tailored to particular strains but also the use of contemporary techniques for cell viability measurement.

The biomass of microorganisms may be employed to create siderophore-producing species and as an inoculum to colonize iron-deficient plant root systems. With the hope that agriscientists will adopt measures for agricultural practices that are both environmentally and economically friendly, the enrichment, amelioration, and integration of microbes, chemicals, and organo compounds in a single formulation will have a significant impact in the future? Therefore, the creation of a suitable system that combines microbial, chemical, and bioorganic substances into a single formulation for the control of plant nutrition is essential for sustainable agriculture. The main focus will be on ongoing research and the use of these cutting-edge techniques for more affordable, eco-friendly, and sustainable agricultural operations.

CONCLUSION

The use of biofertilizers in sustainable agriculture is urgently needed since it opens the door to environmentally friendly fertilizer application methods and sustainable agricultural practices. To boost the stability of biofertilizers and further increase their efficacy and shelf life in the field, current research efforts utilize a variety of metabolites, microbes, and inert materials. Future formulations of microbial mixtures and chemical fertilizers might be improved by the employment of the microbe coating technology in addition to bioencapsulation or carrier-based strategies.

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CHAPTER 22

A BREIF DISCUSSION ON BIOFERTILIZER FROM ALGAE

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ABSTRACT:

Exploration and development of throughput products and strategies for significant increases in yield, decreases in cost, the use of wasteland for cultivation, and environment protection and improvement are required due to the growing demand for agricultural products as a result of population growth and concerns about the quality of food, the environment, and human health. Algal biofertilizers promote plant development, act as natural nutrient reservoirs and recyclers, and have all the benefits mentioned above. Diverse algae have recently been studied for their effects on soil, environment, and agriculture, and new industrial procedures have been created for the large-scale growth of algae and the creation of algal biofertilizers. In this chapter, the various character of algae is introduced as a biostimulant. Along with the roles of algae as biofertilizers, the biochemical components of algae that have an influence on the development of plants are also crucial components of the topic. The chapter also covers contemporary developments in the exploitation, development, and production of new algal biofertilizers along with creative farming practices. A lot of focus is placed on algal strains that can create biofertilizers, how to get algal biomass, and how to utilize it to grow plants. Finally, methods and technology for mass producing algal biofertilizers and growing algae are addressed.

KEYWORDS:

Algae, Algal Fertilizers, Biofertilizers, Biostimulant, Recycling, Sustainable Agriculture.

INTRODUCTION

In the realm of crop production, algae are photosynthetic microorganisms that are utilized as biofertilizers. Algal biomass enhances the absorption of nutrients from fertilizers and encourages the delayed release of nutrients from soil and fertilizers. It also retains nutrients and organic compounds in greater concentrations. Many crops cultivated under normal circumstances or stress benefit from bio stimulants, which are products made from organic material. Biofertilizers are organic compounds or live microorganisms that may improve the soil's nutritional content and thereby promote plant development. Both of microalgae's characteristics increase agricultural sustainability and are piqueing the interest of agrochemical companies and farmers in the algae[1].

Inorganic fertilizers are necessary for sustainable agriculture to boost crop output. However, using inorganic fertilizers excessively is dangerous for both the environment and people. Exploring microorganisms like microalgae, cyanobacteria, and mycorrhizal fungi that may live in association with plants to create biofertilizers is thus necessary. When chemical fertilizers are used extensively, the soil and groundwater get contaminated, which causes incursion in the constrained ecosystem and eventually lowers agricultural output. The drawbacks of chemical fertilizers drive the search for substitute nutrition sources to increase food crop yields while posing less of a threat to the environment. Biofertilizers demonstrate the ability to deliver nutrients by transforming them from an inedible state to a useful one via a biological process, aiding in plant germination and early development. The greatest way to save the environment is to utilize organic biofertilizers since they are not only affordable but also effective. The microalgae demonstrate their value as a biofertilizer by assisting plants in fixing nitrogen. The utilization of blue-green algae is economical, reduces the need for artificial fertilizers, boosts grain output, and reduces pollution. Biofertilizers are a crucial component of biological nitrogen fixation and nutrient delivery systems.

Recently, tiny and marginal growers have started to choose biofertilizers as a supplement to synthetic fertilizers since they offer a sustainable supply of nutrients. The fertilizer industry will be put to the test whether the product's efficacy can be increased, which can be done by creating and launching new fertilizers as well as using current fertilizers more efficiently. Recent technological advancements have made it possible to regulate and limit the release of nutrients, which has the benefit of improving efficiency over a longer time frame and avoiding loss via leaching and volatilization. Seaweeds are widely utilized in crop production to increase soil fertility, however more research is needed to fully understand their bio-stimulatory effects and underlying processes. Many nations employ marine algae as manure, and lately, the potential of seaweeds in modern crop agriculture has been thoroughly researched for the creation of new useful products from seaweeds in the form of biomass and liquid fertilizer. The crucial role that fertilizers play in boosting crop profits necessitates the industrial manufacture of diverse and cost-effective fertilizers[2].

Algae are now the subject of scientific study on a global scale to be effective biofertilizers for sustainable agriculture. The variety of algae and the biochemical components of algal biofertilizers are discussed in the chapter along with their impact on plant development, yield, soil, and the environment. In-depth discussion is also given to new, innovative approaches for producing novel biofertilizers in large quantities from algal biomass. The influence of algal biofertilizers on cultivation is also the focus of efforts to deploy as-developed algal biofertilizers to crops.

Algal biofertilizers and Algae

A Polyphyletic Functional Group is Algae

Microbes that can do photosynthesis are known as algae, and they contain creatures from many different phyla. Cyanobacteria are prokaryotes, whereas microalgae and dime-toms are eukaryotes. It is anticipated that there would be almost 30,000 species of unicellular and intricate multicellular algae in nature. The word "microalgae" is based on function rather than phylogeny. Eukaryotes and prokaryotes, two phylogenetically separate kinds of microorganisms, are both consumed by microalgae. The multiphyletic functional class of photosynthesis-capable autotrophic organisms is known as microalgae. Because of the pigments from photosynthetic processes and other sources, they are colorful. The aquatic environment is home to both freshwater and marine microalgae. Microalgae are typically unicellular and have the ability to form colonies. Chlorophyta, Rhodophyta, Phaeophyta, Euglenophyta, Pyrrophyta, and Chrysophyta are the different subgroups of microalgae. Common names for green, red, and brown algae are Chlorophyta, Rhodophyta, and Phaeophyta, respectively. Through photosynthesis, cyanobacteria are lone prokaryotes that produce oxygen. Cyanobacteria, sometimes known as blue-green algae, are microorganisms that are gaining attention for their potential to enhance long-term farming. Cyanobacteria are regarded as the most successful and resilient prokaryotic microorganisms on earth and are thought to be the first form of life in the history of evolution.

Algal Biofertilizer's Multifaceted Function in Sustainable Cultivation

Algae as biofertilizers serve a variety of purposes, improve the soil's quality and fertility, and promote plant development and production. Algal fertilizers boost soil production by fixing nitrogen and sequestering carbon. They also enhance soil quality by restoring land and enhancing its structure. Through the synthesis of plant growth hormones, biofertilizers accelerate plant development while aiding in defense mechanisms, colonizing plant tissue, and pest management. Blue-green algae are found in freshwater and saltwater environments all over the globe. They use organic acids to increase the bioavailability of phosphorus to plants[3].

Physical, chemical, and biological aspects of the soil are affected. The nitrogen fixation process used by blue-green algae, which convert dinitrogen into ammonia, is inexpensive and only requires very basic inorganic materials. Blue-green algae use nitrogen fixation to boost grain production by 10%–30%. In India, there are 40 facilities for the manufacture of blue-green algae biofertilizer. In addition to producing hydrogen gas and ammonium ions, cyanobacteria also use carbon dioxide and nitrate to build algal biomass. Diazotrophes, a kind of blue-green algae, may be used to produce fertilizers that are affordable, accessible, and safe for ecosystems. Diazotrophe biofertilizers may improve soil gas content, store water, control nitrogen deficit in plants, and raise vitamin B12 levels.

Bioactive Algal Substances

For a plant to thrive, both macronutrients and micronutrients are necessary. The micronutrients include iron, zinc, copper, molybdenum, boron, and chlorine, whereas the macronutrients are nitrogen, potassium, phosphorous, calcium, and magnesium. To maximize the output of cultivated crops, essential nutrients must be present in a certain ratio. Marine algae are non-fossil biogenic resources used as a source of raw materials for industry and in the realms of food, medicine, and botany. The presence of bio-stimulant chemicals in seaweeds and their derivatives is a crucial characteristic of marine algae. Minerals and biomolecules may be found in abundance in marine algae. Additionally, marine algae have higher concentrations of phytohormones, osmoprotectants, and antibacterial substances. Organic farming is necessary, which is why seaweed extract usage has recently increased. Marine macroalgae promote seed germination, lengthen shoots and roots, boost plant health and growth overall, enhance nutrient and water intake, aid in plant resistance to diseases and salt, boost fertility, and clean up contaminated soil. Potassium-absorbing green algae like Coelastrella oocystiformis and Chlorolobion braunii are potential biofertilizers[4]. The two chosen algae have distinct shapes, making them ideal for examining how shape affects potassium absorption. Two separate algal strains are grown for 30 days at various potassium concentrations ranging from 200 to 2,000 parts per million under 5,000 lux to see how well they can absorb potassium. Ash made from algal biomass is created after harvesting, when the algal biomass dries out, and its potassium content is checked. Chlorolobion braunii uptakes potassium more efficiently than Coelastrella oocystiformis cultivated on 400 parts per million potassium ion concentration, according to an analysis of the ash content. At this concentration, Coelastrella oocystiformis absorbs 74.8% of the potassium.

Algal extracts include macromolecules such polyunsaturated fatty acids, proteins, lipids, and carbohydrates. The algal extracts are also abundant in a wide variety of physiologically active substances. Antioxidant characteristics may be found in polyphenols, tocopherols, vitamin C, and amino acids that resemble mycosporine. Chlorophyll and carotenoids are pigments that absorb light. Phycobilins include phycocyanin and phycoerythrin. The vital abilities of phytobilins to combat bacteria, fungus, viruses, oxidation, inflammation, and tumors are evident. The creation of novel techniques for extracting active bio-stimulants has lately been a focus of study on a global scale. Enzymes, microwaves, high pressure, supercritical fluid, and ultrasound are used in the extraction processes to improve the efficiency and stability of the bio stimulants obtained from seaweeds[5].

Application Methods for Algal Biofertilizers

Biofertilizers made from Algal Extracts

Algal extracts stimulate plant development, which improves the effectiveness of sources of vital nutrients. Low crop yield, a lack of water, increasing environmental pollution, and the need to limit the use of inorganic fertilizers make the use of innovative algae extracts and irrigation techniques necessary. Chlorella sp. algae extracts are used. Boost the amount of nitrogen, phosphorus, and potassium that broccoli plants absorb from the soil and promote plant development in general when grown on sandy loam soil. Different combinations of organic, compost, biological, and mineral nitrogen sources were investigated in order to evaluate the effectiveness of algal extract. Plant growth is impacted by the algal extract in conjunction with nitrogen sources. The effects on vegetative portions include a rise in plant height, leaf count, leaf area, and fresh shoot weight. Chlorophyll a, b, and vitamin C concentration increases as a result of the influence on biochemical components. When the algal extract is sprayed on plant leaves, the effectiveness of the extract is significantly more obvious. The macro and micronutrients, organic acids, hormones, and amino acids necessary for plant development are all present in the algal extract. Either the soil or the plants are sprayed with the algal extract. The development of vegetative components and the production of flowers in freesia plants are significantly influenced by the spray of an extract from the leaf of an algae.

Water accessibility is receiving attention and calls for an increase in water availability for agriculture in order to fulfill the global need for food. One drawback of a great strategy to increase water proficiency is the potential for adverse effects on plant physiology and productivity. This strategy is deficit irrigation. The effect of marine algal extracts on the resilience of onion plants cultivated in places with decreased water supply to drought is not well understood. In field tests with split-plot design in four replicates, the impact of foliar spraying extracts from the marine algae Amphora ovalis on onions grown under normal soil water availability and under stress with 50% available soil water is examined. When algal extract is applied as a foliar spray, onion plants' absorption of NPK and bub size both significantly increase statistically. Algal extract also lessens the effect of drought by enhancing chlorophyll synthesis. During drought, plants transfer energy consumption from chlorophyll synthesis to start production of proline and phenols, which are known to withstand water.

In cardoon plants, there are a number of phenolic chemicals that have been used medicinally in various ways. Analysis of growth indicator parameters, including chemical constituents, height, and leaf count, fresh and dry mass of the plant, and seed number and weight after foliar application of various concentrations of four algal extracts from Spirulina platensis, Chlorella vulgaris, Amphora coffee-aeformis, and Scenedesmus obliquus, is done to determine the effect on growth, seed production, and chemical composition of the cardoon plant. When compared to control plants, the usage of Spirulina platensis extract considerably improves the morphological characteristics of cardoon. The amount of fixed oil and total carbohydrates in cardoon plant are increased by scenedesmus obliquus extract. Chlorella vulgaris extract promotes the formation of flavonoids and shields cells from free radical activity. Chlorogenic, caffeic, and vanillic phenolic chemicals are much more abundant in plants treated with Amphora coffeaeformis extract than in control plants[6].

In horticulture, extracts from marine algae are utilized as biofertilizer. The treatment boosts the overall growth and yield of the plant. The impact of extracts from Ascophyllum nodosum on the development of Vitis vinifera cv. Plants from Feteasca Alba are studied. There are three concentrations of the marine algae extract used. An algae extract from the experimental studies demonstrates the impact on fertility coefficients, the length and diameter of the shoot, and the area of the leaf. In comparison to plants grown on lower concentrations of algal extract, plants grown on greater concentrations of concentrates had higher absolute and relative fertility coefficients.

The application of an algal extract to leaves demonstrates the enhanced development of plant vegetative components. To promote wheat seed germination and seedling growth, extracts from Codium tomentosum and Sargassum vulgare, respectively, are employed as liquid fertilizers. The effects of marine green and brown algae extracts on seed germination, seedling growth, and chlorophyll content are examined by utilizing distilled water to apply liquid fertilizer in different quantities ranging from 10% to 50%. Before being transferred to Petri plates, seeds are first treated in liquid fertilizer for 12 hours. Only water is used to soak seedlings for control trials. It was discovered that Codium tomentosum and Sargassum vulgare seeds, respectively, ger-minate in 20% algal extract at rates of 98% and 97%, respectively. By lengthening shoots and roots and increasing the dry weight of seedlings, the application of liquid fertilizer encourages the development of vegetative components. Algal fertilizer increases the amount of carotenoid and photosynthetic pigment in leaves[7].

Extracts from marine algae have the potential to replace artificial fertilizers in agricultural production since they give nutrients and encourage plant development. On the leaves of brinjal seedlings, Solanum melongena, growing in experimental pots and under natural settings, a liquid extract from the brown algae Stoechospermum marginatum is sprayed. After 30 and 180 days, an analysis of the growth and chemical parameters reveals a rise in the length of the shoots and roots, the area of the leaves, and the mass of the living and dead plant. Additionally, algae strengthens the chemical makeup by increasing the amount of moisture, chlorophyll, proteins, and lowering sugar. By using algal biofertilizer, the activity of ascorbic acid and nitrate reductase is also increased. Fruit quantity and bulk are increased when algal biofertilizer concentrations are lower. Comparatively, a larger concentration of algal bio-fertilizer has an inhibitory impact on measures of plant growth.

The green alga Chlorella sp. Salix viminalis willow plants may root and grow more by greatly boosting metabolism. Plant cuttings are cultivated with either sonicated or non-sonic biofertilizers present. There are two ways to nourish plant cuttings using biofertilizer. Plant cuttings are rooted on a universal horticulture substrate in one method. After that, rooted cuttings are placed in a vegetation chamber and covered with biofertilizer for 4 days. The second approach involves rooting and growing untreated plant cuttings in substrate that has been soaked with biofertilizer.

Cellular extract and biomass from green algae Acutodesmus dimorphis both show properties of biostimulants and are used as biofertilizers to Microwave-assisted extracts from Polysiphonia, Ulva, and Cladophora are obtained by keeping powdered algal biomass with water in Teflon chambers inside a microwave oven at 25°C-60°C and characterized for the presence of biostimulant compounds. Seaweed extracts prepared using a microwave have a high polyphenol content but little fatty acids. While the concentration of micro- and macroelements in an extract rises with temperature, the concentration of polyphenols decreases. Lepidium sativum plant development and germination are impacted by a seaweed extract heated in a microwave without changing the plants' appearance. Potential biofertilizers for agriculture include seaweed extracts that have been heated in a microwave[8].

In Arabidopsis thaliana plants, Ulva intestinalis extract influences germination and root elongation by stimulating these processes while inhibiting the development of lateral roots. Studies reveal that a greater extract concentration inhibits seed germination and inhibits root development. Different stimulation mediators are affected by the algal extract differently than seeds. Being present

Biofertilizer for Algae

A greater concentration of Al3+ in Ulva shows that ethylene and cytokinin are involved in the slowed development of roots. The findings of the experiments suggested that for optimal output, biofertilizers should be used carefully.We are looking at the effects of foliar application of algal extract and two distinct irrigation techniques, seeping and aerosol. On plant growth characteristics, applying an algal extract from the blue-green algae Spirulina platensis to the leaf is particularly effective. Systems of seeping and aerosol irrigation are very effective, but not for the size of the leaf, the height of the plant, or the length of the spike.Investigated is the effect of applying algal extract on the leaves of the freesia plant. Three duplicate applications of the algal extract are made. The algal extract is administered three times with a 15-day gap in the first trial. Second, 10 day old seedlings are treated with three different extract concentrations.

Because the algal extract has a greater leaf and photosynthetic area, plants develop and produce more flowers. Additionally, an increase in the length of the stalk housing the flower clusters and inflorescence is seen. Algae are combined in groups and applied to tomato plants as biofertilizers. Algal biofertilizers are sprayed over leaves and seed primers as an extract. Mixed algae biofertilizers boost the macromolecules and biochemicals that promote plant development.Spinacia olerasea L. grows more quickly when multicellular blue-green microalgae Spirulina platensis extract is applied to the soil or used as a foliar spray. .By raising the amount of photosynthetic pigment present, algal extract application raises the values of growth indicator parameters. Algal biofertilizer lowers plants' need for nitrogen by 20%.

Algal Strains and Algal Biofertilizer Added to the Soil

Marine microalgae strains improve maize plant germination and early development, which increases yield. To achieve this, C. Along with the cow dung, vulgaris and Spirulina platensis are introduced to the soil for 2.5 months. In greenhouses, biofertilizer-supplemented maize plants are cultivated. The increase in growth and productivity demonstrates the potential of marine microalgae as fertilizers for maize crops. Using S. platensis and then C, then animal manure. By increasing the availability of nutrients needed for onion plant development, vulgaris boosts onion growth and production. The tactic raises the plant's height, leaf count and weight, as well as its fresh and dry weight.

Additionally, the introduction of marine strains enhances the onion bulb's size, weight, and neck thickness, all of which contribute to an increase in production. In addition to improving the biochemical makeup of onions in terms of soluble sugars, total phenols, free amino acids, and indoles, biofertilizer also boosts the color content of onions. Brassica napus cultivated indoors produces more of its leaves when sea algae Ulva lactuca, cysto-seira spinose, and Gelidium crinale are used as biofertilizers in the soil. Seaweed is manually gathered at low tide. Epiphytes and sand particles may be removed by combing weeds and washing with saltwater. The remaining salts are eliminated by rinsing with tap water. Seaweed is ground into a fine powder and used as a bio-fertilizer after the plants are dried for six days in the air.

A mixture of 1.0 kg of soil and three grams of algal powder is irrigated twice daily for seven days. Inhibition of chlorophyll a and b, total carbohydrate buildup, and hormones that promote growth is reduced when three seaweeds are combined. Osmoprotectants and antioxidants are both increased by the combination. Phenols, flavonoids, and anthocyanin are examples of antioxidants, whereas total carbohydrates and proline are osmoprotectants enhanced by the use of a combination of seaweeds. Growth-promoting hormones including indole acetic acid, indole butyric acid, gibberellic acid, and cytokinins are increasing, which is why canola is growing more[9].The amount of phosphorus that plants absorb when phosphate fertilizers are combined with biomass produced by microalgae. The microalgae are grown on wastewater for this reason. The total phosphorous content of Pennisetum glaucum L. was examined. Grown on various ratios of triple phosphate and algal biomass reveals that 12% algal biomass releases the most phosphorous both inside and outside of the greenhouse. The values of the parameters examined in the plant drop as the fraction of algal biomass rises more. However, there is no difference in phos-phorous diffusion in the soil when using 12% microalgae biomass and triple phosphate. In place of expensive chemical fertilizer, the marine microalgae Chlorella vulgaris and Spirulina platensis increase rice output by 20% when applied under surface irrigation in clay loamy soil.

A commercial biofertilizer called Algaefert is based on an Ascophyllum nodosum extract. Jatropha curcus L. is utilized with algaefert, microbien, and phosphorein. Seedlings, and the impact of biofertilizer on their development and chemical makeup is examined. After 30 to 60 days after planting 200 g of DAP or compost per container, three fertilizers are applied to the pot. For Jatropha curcus L., the application of algae, microbien, and compost significantly enhances the length and width of the stem, leaf number per plant, and leaf area all of which are markers of growth. Chlorophyll a and b, a carotenoid pigment, carbohydrates, phenols, and indoles are also increased by three fertilizers.

Indole and phenol levels in Jatropha curcus seedlings are reduced by compost application. Wastewater serves as the source of nutrients for microalgae growth, and the biomass is utilized to produce crops. Sewage is used to create filamentous macroalgal or unicellular microalgal biomass. Both times, a carrier material like vermiculite or compost is combined with the algal biomass. The crop Triticum aestivum is grown on either kind of algal biomass. The levels of accessible nitrogen, phosphorus, and potassium in soil as well as nitrogen-fixing capability considerably rise with filamentous macroalgal biomass. Biomass from unicellular microalgae significantly increases the carbon content of microbial biomass. With a value of around 4% nitrogen in grains, both forms of algae produce NPK components in roots, shoots, and fruit. The biofertilizer, when applied during the harvesting process, also boosts the dry plant mass.

To improve soil fertility, algal biomass derived from wastewater treatment using a nutrient recycling strategy is introduced. The biochemical makeup of the land, particularly the algae capable of forming soil biofilms, is less well understood as a result of the large addition of living algae to the soil in greater quantities. Plant and microbial interactions are impacted by soil biofilms. Particularly Chlorella sorokiniana, a genus of unicellular algae, is used in wastewater control systems. The algae's cell suspension boosts the biomass of bacteria in the soil. The presence of bacteria in the soil is suggested by increased CO2 produced by the land. The overall amount of carbon in the soil is also increased by algal biofertilizer in the form of a film[10].

Goods made from biomass that includes Chlorella sp. Corn is grown with the help of the biofertilizers Neochloris conjucta and Botryococcus braunii, which have an effect on plant development and soil nutrient absorption. Four different quantities of the residue from microalgae digestion are applied to maize plants. Botryococcus braunii and Neochloris conjucta concentrations that are higher inhibit plant development and nutrient absorption. The chlorella sp. significantly enhances nutrient absorption and plant development. Wheat and barley seeds develop faster and have better germination rates when treated with biofertilizer made from Scenedesmus obliquus biomass. The effects of applying blue-green algae to the soil-on-soil fertility and mustard seed germination are studied. Clay and blue-green algae are mixed and applied to the surface of containers holding mustard seedlings. Analysis of soil quality before and after blue-green algae treatment reveals that blue-green algae improve soil quality, which affects seed germination.

Rice fields with acidic soil are prepared with blue-green algae, and seedlings are planted in areas with standing water. The fields get a dose of 0.05 kg/m2 of biofertilizer, which is a mixture of several strains of blue-green algae, after 10 days. The findings demonstrate that rice plants are robust and healthy, with more densely packed leaves than the control. Blue-green algae boost rice grain production by 10%, both in terms of quantity and mass. Anabeena sp. is applied together with NPK to rice that is cultivated in sandy loam fields and greenhouses, and the results are compared to control plants. In greenhouse plants, blue-green algae significantly increase the phosphorus and potassium content of seeds and plants. The use of blue-green algae significantly increases the rice seed mass. The cost of synthetic fertilizer is reduced when blue-green algae are used in rice fields, and they also show promise as a biofertilizer. In place of sowing seedlings, rice plants are now planted immediately. The underlying process for how blue-green algae stimulate plant development is yet unknown, however. Blue-green algae are suitable and affordable biofertilizers for rice farming since they are a component of the natural eco-system that may be found in the standing water of rice fields.

In the cultivation of rice, blue-green algae are employed as a biofertilizer. Other crops are being grown using blue-green algae as well. It is explored how blue-green algae affect the functionality of nitrogen reductase in Capsicum annum. You may use blue-green algae alone or in conjunction with vermicompost. When combined with vermicompost, blue-green algae boosts nitrate reductase activity. Blue-green algae are produced in beds of plants grown for medicinal purposes on nitrate-free substrate. The nitrogen in the atmosphere may be changed by blue-green algae into a form that plants can utilise. Hormones utilized by plants are produced by certain cyanobacteria. Effects of the blue-green algae Nostoc carneum, Wollea vaginicola, and Nostoc punc-tiforme on the development of Matricaria chamomilla L. plants and the generation of essential oils. By adding blue-green algae suspension to the soil, plants are studied in the greenhouse. After 15 days after planting, plants are administered blue-green algae in suspension. The output of essential oil and root elongation are both considerably impacted by blue-green algae. According to a high-performance liquid chromatography examination, indole acids, which function as hormones and promote plant development, are produced by blue-green algae.

By enabling a regulated and gradual release of nutrients, technology improves the effectiveness of algal fertilizer products, prolongs their useful lives, and reduces loss through leaching and volatilization. The integration of microalgae into the polymeric urea-formaldehyde matrix results in a slow-release biofertilizer. The quantitative study of macro- and micronutrients in the microalgae is made possible by techniques such as titration, ultraviolet, and atomic absorption spectroscopy. The investigation of the polymeric urea-formaldehyde matrix and included chlorella spinosis will be possible thanks to the techniques of structural characterisation infrared spectroscopy and scanning electron microscopy. Nitrogen, phosphorous, and potassium are slowly released from the formulation in vitro, with maximal releases of 28%, 26%, and 46% over the course of 30 days. The new formulation, which is based on nutrients of a natural origin, performs better in vivo than traditional commercial fertilizer.

In comparison to artificial fertilizer and vermicompost, de-oiled waste from microalgal biomass boosts growth and yield in the long-term cultivation of rice crops. Scenedesmus sp. is raised in flue gas and sewage. Microalgae in ponds near raceways. To provide a 100% nitrogen supply, microalga, chemical fertilizer, and vermicompost are immediately applied to the soil, either separately or in conjunction with one another. The biggest boost in plant growth, including height, tiller count, grain production, and weight, is shown when microalga and chemical fertilizer are combined.

It aids in halting the transformation of land into desert. To fulfill demand, mixed planting practices and the use of chemical fertilizers lead to lower fruit quality and less profitable output. The lengthy generation period also has an impact on fruit output. In order to satisfy demand, plantlets generated in vitro cultures are put in soil to produce true-to-type clonal plants. These plantlets emerge from proliferating calluses for large-scale manufacturing. The application of the microalga Tetraselmis sp. improves the survival of date palm plantlets transplanted from the culture medium to soil. The biofertilizer aids in plants' acclimation to soil from culture. Plant growth is tracked for three months after adding microalga to soil without synthetic fertilizer or soil that has been modified with manure. By promoting total plant development via improved root formation, an increase in root length, leaf number, and stem girth, as well as an increase in chlorophyll content, microalga boosts plant lifespan to 100%. Additionally, microalgae raise the NPK levels in the soil, which are crucial nutrients for plant development.

Algal Culture and Algal Biofertilizer Production

Large-scale algae farming has become more popular lately for the production of byproducts and biofuels. It is not economically feasible for the industry to produce cost-effective biofertilizer by growing algae on a wide scale since doing so would demand a lot of nutrients. For the large-scale development of algae, an inexpensive supply of nutrients is needed. Utilizing wastewater for algae farming not only offers inexpensive nutrients but also helps regulate water use and recycle non-renewable resources like phosphorus. Organic and inorganic nutrients including carbon, nitrogen, and phosphorus are all present in large quantities in wastewater. Algae are grown using wastewater from home usage, the soybean and potato processing business, the carpet industry, and aquaculture. The growing of algae for the manufacturing of biofertilizers uses solid waste from agricultural achievements and industries based on agriculture, food, dairy, and poultry manure, which is nutrient-rich.

A cycle economy based on biotechnology is created by taking use of microorganisms' utilization of nutrients taken up from waste in the biotechnology sector to generate usable goods including bioactive compounds via biorefinery. Scenedesmus obliquus successfully ingests nitrogen, phosphorus, and chemical oxygen requirement from brewery waste. Scenedesmus obliquus is grown using trash from breweries. The resultant biomass is processed in a biorefinery to create biofertilizer, along with other beneficial byproducts and chemicals. Phenols, flavonoids, hydrogen, oil, and biogas are some of the byproducts. The purified strains of microorganisms are cultured in sizable fermenters or photobioreactors to create biofertilizers. The method makes use of algae's capacity to carry out photosynthesis. In photobioreactors, microorganisms are produced on a huge scale using either natural or artificial light. The benefit of free sunlight for photosynthesis is its efficiency. There are open systems and closed systems for the bioreactors. Using closed photobioreactors eliminates the drawback of contamination in open bioreactors. Additionally, the closed system boosts the cell densities and surface-to-volume ratios of the grown microorganisms.

A few regionally adapted strains of blue-green algae are inoculated in an open photobioreactor for the commercial production of algal biofertilizer. There are several varieties of open photobioreactors, including cement tanks, shallow steel trays, pits lined with plastic, and open fields. Before inoculation, a combination of fertilizers, soil, lime, and insecticides is applied to the photobioreactor. Fertilizer serves as a source of nutrients. Lime modifies the soil's pH. Blue-green algae may grow best at temperatures between 35°C and 35°C. Dry algal bio-mass is separated from the soil, then it is ground and packed.

CONCLUSION

There is a growing need for food and agricultural goods, which necessitates sustainable farming practices and increased yields. The widespread use of chemical fertilizers is costly, detrimental to the environment, ecology, and soil directly, and indirectly harmful to human health. Recent research demonstrate significant progress in the study of new algae strains and the creation of algal fertilizers.

Algal biofertilizer production is economical and risk-free. Algal biofertilizers may replace chemical fertilizers for sustainable agricultural cultivation since they enhance yield, are safe for the ecology and environment, and boost crop output. In addition, algal biorefineries produce useful byproducts in addition to biofertilizers.

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CHAPTER 23

MICROBIAL BIOFERTILIZERS: CATEGORIES AND USES

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ABSTRACT:

Due to contemporary agriculture's greater reliance on synthetic chemical fertilizers, the soil has deteriorated and there has been a rise in air and water pollution as well as the greenhouse impact. To produce enough food at a reasonable cost for the growing world population, there is also an urgent need for sustainable agriculture techniques with fewer energy and environmental issues. As a result, biofertilizers made of bacterial, fungal, and algal microorganisms have been recommended as workable remedies for large-scale agricultural practices that are not only organic, eco-friendly, and affordable but also sustain the soil's structure and biodiversity on agricultural land. Microbial biofertilizers encourage plant development in addition to enriching the soil with nutrients by improving the efficiency of nutrient absorption or availability for the plants and by controlling soil-borne illnesses.

KEYWORDS:

Agriculture, Agrochemicals, Biofertilizer, Beneficial Microbes, Soil-Borne.

INTRODUCTION

In order to replenish nutrients, biofertilizers primarily fix atmospheric nitrogen, solubilize phosphorus, and create compounds that encourage plant development. Rhizobia and other genera of nitrogen-fixing bacteria are employed to boost the development of legumes and other crops. Azolla and blue-green algae also contribute to the practical agriculture's nitrogen budget. Many plants rely on arbuscular mycorrhizal fungus for the absorption of phosphorus and a number of other minerals. The solubility and availability of phosphorus to plants, as well as crop output, may be increased by phosphorus-solubilizing bacteria like Azotobacter and Azospirillum that fix atmospheric nitrogen. In addition, Azospirillum offers further advantages such the ability to produce chemicals that stimulate growth, disease resistance, and drought tolerance. Thus, using microbial biofertilizers is an efficient way to improve and maintain the soil's nutrient economy while using less chemical fertilizers for successful and sustainable agriculture.

Fertilizers are organic or inorganic substances that, when applied to plants, soil, or via fertigation, may enhance soil fertility, crop development, and plant health. These enable plants to access 36 essential macronutrients, including zinc, copper, iron, boron, and molybdenum, as well as a large number of micronutrients, including phosphorus, potassium, calcium, sulfur, and magnesium. Standard fertilizers with nitrogen, phosphorus, and potassium are in high demand. . In order to address malnutrition and micronutrient shortages of copper, iron, zinc, iodine, selenium, and fluorine in crop plants, micro-enriched fertilization, which involves the addition of micronutrients to these basic fertilizers, has spurred agronomic 46 bio-fortification. For instance, it has been shown that fertilizers with additional zinc boost cereal grain output through improving seedling establishment and environmental stress tolerance. However, despite the abundance of nutrients in soil, one barrier to plant growth is their inaccessibility to plants, particularly nitrogen and phosphorus. While the majority of nitrogen is found in soil organic matter, forcing plants to compete with soil microbes for it, phosphorus precipitates with iron and aluminum or with calcium[1], [2].

The exponential rise in the human population has necessitated a parallel supply and production of food, especially from plants. As a result, a highly productive and intensive agricultural system has been largely achieved through the use of synthetic chemical fertilizers of nitrogen and phosphorus. Modern agriculture's increased dependence on an excessive, unbalanced, and constant synthetic input of chemical fertilizers has worsened soil quality, surface and ground water, as well as further decreased biodiversity and stifled ecosystem. Chemical fertilizers are produced and transported using fossil fuels, which release airborne nitrogen and carbon dioxide pollution that is deposited in terrestrial ecosystems. Additionally, if chemical fertilizers are applied to soil in excess of what is needed by crops, they are stored by plants and frequently result in potential losses due to increased nitrate and phosphorus concentrations in water bodies that cause eutrophication and hypoxia in lakes and estuaries as well as environmental pollution issues due to emissions of greenhouse gases like nitrous oxide from fertilizer production and application.

DISCUSSION

Microbes that Promote Plant Growth

In addition to bacteria that fix nitrogen and dissolve phosphorus, there are others that may be employed as biofertilizers because they boost plant development by creating compounds that encourage growth. (Bashan 1998). For instance, it was discovered that the rhizospheres of Bacillus pumilus and Bacillus licheniformis generate significant amounts of the physiologically active plant hormone gibberellin. Paenibacillus polymyxa, however, demonstrated a range of advantageous traits, including nitrogen fixation, phosphate solubilization, and generation of antibiotics, cytokinins, chitinase, and other hydrolytic enzymes, as well as improvement of soil porosity. Additionally, it has been claimed that certain Azospirillum species synthesize plant hormones. These point to the potential of various bacteria as biofertilizers, which may call for more research.

Rhizobacterial plant growth-promoting mechanisms of antagonism against phytopathogenic microorganisms include the production of antimicrobial metabolites like siderophores and antibiotics, gaseous products like ammonia, and fungal cell wall-degrading enzymes that cause cytolysis, leakage of ions, membrane disruption, and inhibition of mycelial growth and protein biosynthesis. For instance, some strains of Pseudomonas may create antifungal metabolites such phenazines, pyrrolnitrin, pyoluteorin, and cyclic lipopeptides of viscosinamide that can shield sugar beet against Pythium ultimum infection. Pathogenic microbes like Pythium ultimum, Rhizoctonia batatticola, and Fusarium oxysporum are prevented from growing and proliferating by Pseudomonas fluorescens' production of iron-chelating siderophores like pseudobactin and pyoverdin that bind and take up ferric ions.

In addition to creating resistance to Botrytis cinerea on bean and tomato and Colletotrichum lindemuthianum on bean, Pseudomonas aeruginosa also generates the siderophores pyoverdine, pyochelin, and salicylic acid. The extracellular chitinase and laminase produced by certain Pseudomonas species, however, may lyse the mycelia of Fusarium solani. Additionally, biofertilizers provide defense against certain plant diseases, insect pests, and soilborne illnesses. For instance, Azotobacter contaminates the soil with antibiotics that stop the spread of infections like Pythium and Phytophthora that are soilborne [3]

Biofertilizer Compost

Compost is a brittle, murky substance that is decaying and forms a symbiotic food web in the soil. It includes around 2% (w/w) of nitrogen, phosphate, and potassium.Together with bacteria, earthworms, and dung beetles, and potassium. The 1 Microbial Biofertilizers: Categories and Uses 9 Microbial oxidation of organic solid residues results in the production of humus-containing material, which can be used as an organic fertilizer to sufficiently aerate, aggregate, buffer, and keep the soil moist, as well as to increase the diversity of soil microbes and provide crops with beneficial minerals. Straw, leaves, cattle-shed bedding, fruit and vegetable wastes, biogas plant slurry, industrial wastes, municipal rubbish, sewage sludge, industry waste, etc. are just a few of the elements used to make compost. Different decomposing microorganisms, such as Trichoderma viridae, Aspergillus niger, Aspergillus terreus, Bacillus species, and several Gram-negative bacteria (Pseudomonas, Serratia, Klebsiella, and Enterobacter), among others, that have cellulolytic or lignolytic activity and other activities as well as proteolytic activity and antibiosis (by producing antibiotics) that suppress other parasit (Boulter et al. 2002). Vermicompost is a crucial type that contains earthworm cocoons, excrement, microorganisms (such as bacteria, actinomycetes, and fungi), and various organic materials. These materials provide nitrogen, phosphorus, and potassium as well as a number of micronutrients. Vermicompost also effectively recycles animal waste, agricultural residues, and industrial waste while using little energy.

Microbial Biofertilizer Application Procedures

The main delivery method for biofertilizers is traditional carrier-based inoculants, which has the advantages of being less expensive and simpler to make. Cultivating microorganisms, processing carrier material, combining carrier material with broth culture, and packaging are all steps in the mass manufacturing of biofertilizers as shown in Figure 1. The best carrier materials for making biofertilizers must be less expensive and available locally[4].

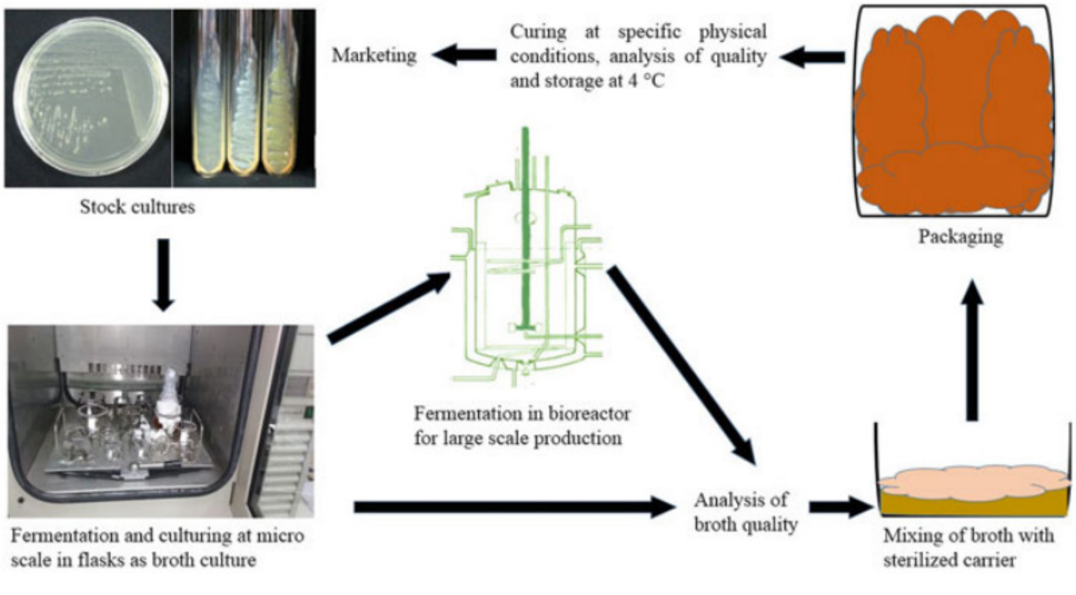

Figure 1: Representation of mass production of bacterial biofertilizers.

They must be readily accessible, simpler to process, non-toxic, organic in structure so that they stay biodegradable, have a high water-holding capacity, transport more bacterial cells, and enable their survival for extended periods of time. The manufacturing of high-quality biofertilizers often uses a variety of carrier materials, including neutralized peat soil/lignite, vermiculite, charcoal, press mud, farmyard manure, and soil mixture. However, they may have drawbacks such as a shorter shelf life, sensitivity to temperature changes, susceptibility to contamination, and reduced effectiveness due to low cell numbers. As a result, liquid formulations for Rhizobium, Azospirillum, Azotobacter, and Acetobacter have been developed. These formulations, while more expensive, have advantages such as easier production, higher cell counts, longer shelf lives, no contamination, storage up to 45 C, and greater competence in soil. Nevertheless, the methods for applying microbial biofertilizers include treating the seeds, dipping the roots of the seedlings, and applying the soil.

Treatment of Seeds

The most popular, efficient, and economical approach used for all kinds of inoculants is seed treatment. The seeds are combined and evenly coated in a slurry 200 mL of rice kanji mixed with inoculant, shade-dried, and then seeded within 24 hours. For liquid biofertilizers, coating may be done in a bucket if amount is large or a plastic bag if quantity is modest, depending on the number of seeds. It is possible to treat seeds with two or more bacteria, providing the maximum amount of each bacterium on each individual seed necessary for better results. For example, nitrogen-fixing bacteria like Rhizobium, Azotobacter, and Azospirillum can be taken along with phosphorus-solubilizing microbes. For instance, Azotobacter, Rhizobium, and Agrobacterium are used to treat seeds for a variety of plants, including grains like wheat, oat, and barley, oil seeds like mustard, seasum, linseeds, sunflower, and castor, millets like pearl millets, finger millets, and kodo millet, forage crops and grasses like bermuda grass, sudan grass, napier grass, para grass, star grass.

Root Dipping of Seedlings

For plantation crops like cereals, vegetables, fruits, trees, sugarcane, cotton, grapes, bananas, and tobacco, this application is typical. The seedling roots are submerged for a sufficient amount of time in a water suspension of biofertilizer nitrogen-fixing Azotobacter or Azospirillum and phosphorus-solubilizing microbial biofertilizer) For example, vegetable crops are treated for 20 to 30 minutes, whereas paddy is treated for 8 to 12 hours prior to transplanting.

Application to Soil

In this method, biofertilizer is mixed with or administered alone straight to the soil. Overnight, a combination of cow dung, rock phosphate, and phosphate-solubilizing microbial biofertilizer is left in the shade while preserving its moisture level at 50%, after which the soil is treated. (Pindi and Satyanarayana 2012). Rhizobium for leguminous plants or trees and Azotobacter for tea, coffee, rubber, coconuts, all fruit/agroforestry plants for fuelwood, fodder, fruits, gum, spice, leaves, flowers, nuts, and seeds are two examples of biofertilizers that use soil application[5], [6].

Microbial Biofertilizers Readily Available

Numerous microbial biofertilizers, sold on the market as dried or liquid cultures under various brand names, are used to improve soil fertility and plant development, among other things. For instance, rhizobia biofertilizers may fix 50 to 300 kg of nitrogen per hectare, increasing yield by 10 to 35% while still preserving soil fertility and leaving some nitrogen behind for subsequent crops. In addition to maintaining soil fertility, producing growth-promoting compounds like vitamin B complexes, indole acetic acid, and giberellic acid, the Azotobacter biofertilizer used for almost all crops can fix 20–40 mg N g1 of carbon source, causing up to 15% increase in yield. It also helps with biocontrol of plant diseases by suppressing some of the plant pathogens. The non-specific, all-purpose phosphorus-solubilizing bacterial biofertilizers generate enzymes that convert the insoluble organic phosphorus into a soluble form, enhancing crop production by 10–30%[7]–[9].

CONCLUSION

In terms of a practical replacement for chemical fertilizers, which are linked to a number of environmental risks, biofertilizers are a crucial part of sustainable organic farming in contemporary agricultural practices. Biofertilizers can produce hormones and antimetabolites to support root growth, fix atmospheric nitrogen in the soil and root nodules, solubilize phosphate from insoluble forms like tricalcium, iron, and aluminum phosphates into available forms, sift phosphates from soil layers, and decompose organic matter for soil mineralization. This results in higher crop yields, improved soil structure by influencing soil particle aggregation for better water relation, pure water sources, and induced drought tolerance in plants by improving leaf water and turgor potential, preserving stomatal function, and increasing root development.

However, a greater demand for and understanding of the usage of biofertilizers among farmers and planters might open the door for new entrepreneurs to enter the biofertilizer production industry, which also needs government assistance and encouragement. As a necessary component of sustainable agriculture, biofertilizer technology must be appropriate for the social and infrastructure needs of the users, economically feasible, renewable, usable by all farmers, stable in the long run, acceptable to various social groups, adaptable to local conditions and different cultural patterns of society, practically implementable, and productive. Thus, it is clear that thorough practical training of dealers and farmers is necessary to improve knowledge of the importance and economic viability of using biofertilizer technology.

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CHAPTER 24

MICROBIAL BIOFERTILIZERS: CURRENT DEVELOPMENTS AND PROSPECTS

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ABSTRACT:

By populating the rhizosphere and making the nutrients freely available to plant root hairs, biofertilizers, which include a range of bacteria, have the ability to improve plant nutrient absorption. The composition, cost-effectiveness, and environmental friendliness of biofertilizers are widely established. These are potent substitutes for the risky synthetic fertilizers. This chapter discusses various microbial biofertilizer types, including symbiotic and free-living nitrogen-fixers, phosphorus-solubilizes, and mobilizers, as well as their formulations, applications of a few commercially available biofertilizers toward sustainable agriculture, and recent efforts to develop next-generation biofertilizers.

KEYWORDS:

Bacteria, Biofertilizers, Microbial, Nitrogen-Fixers, Sustainable Agriculture.

INTRODUCTION

For the continuing and effective production of crops and wholesome food to fulfill the needs of a growing population, soil nutrients are very important. Their sufficiency is a crucial element of agriculture that is sustainable. Fertilizers are very necessary to agriculture in order to increase crop output. Chemical, organic, or biofertilizers are the three types of fertilizers most often employed, and each has unique properties that may be utilized to improve soil fertility and crop development. Chemical fertilizers are utilized to meet the plant's nutritional needs quickly and provide results. While its usage offers highly concentrated nutrients, it also comes with a number of drawbacks, such as water pollution and environmental harm from chemical fertilizers that are washed away or evaporated, respectively. In this opinion, biofertilizers are among the most promising ways to increase crop output in an environmentally acceptable way. The dynamics of several processes, including the breakdown of organic matter, the availability of different plant nutrients like iron, magnesium, nitrogen, potassium, and phosphorus, and the promotion of plant development, are significantly regulated by plant growth-promoting microorganisms[1].

It is now well acknowledged that microbial inoculants are the key element of integrated nutrient management, which promotes sustainability. Furthermore, by reducing fertilizer dosages and ultimately collecting more nutrients from the soil, these bio inoculants may be employed as a cost-effective input to increase crop output. When given to plants via soil or seed, bio-based fertilizers help them absorb nutrients through their interactions in the rhizosphere. They are essentially preparations of live cells or latent of effective potential microbial strains. The technique used to produce biofertilizers and bio inoculants is rather straightforward, and installation costs are extremely low. In the previous several decades, significant advancements have been achieved in the study and use of various biofertilizers.

The variety of microorganisms that promote plant development, as well as the business side and technology for producing biofertilizers for agricultural and environmental sustainability, are the topics of the current study[2].

DISCUSSION

Microbial Biofertilizers' Class and Biodiversity

Microorganisms that Fix Nitrogen

Symbiotic nitrogen-fixing biofertilizers: These are the most well-known and widely used symbiotic nitrogen-fixers. They are members of the Rhizobiaceae family and primarily comprise the genera Allorhizobium, Azorhizobium, Bradyrhizobium, Mesorhizobium, Sinorhizobium, and Rhizobium. Rhizobium is a kind of symbiotic bacterium that coexists with its host plants in the form of a mutualistic relationship in the root nodules. Rhizobium essentially fixes atmospheric N2 gas in the root nodules by converting molecular N2 to NH3, which is subsequently used by plants to synthesize a variety of proteins, vitamins, and nitrogen-containing chemicals. A complex enzyme called nitogenase, which has dinitrogenase reductase with iron as a cofactor and dintrogenase with molybdenum and iron as a cofactor, is responsible for N-fixation.

It has been shown that both symbiotic and free dwelling microbes include the genes for nitrogen fixation, or nif genes. Legumes are less reliant on chemical N fertilizers than the majority of other non-legume crops because Rhizobium has the capacity to fix nitrogen. Rhizobium inoculation is a well-known agricultural method that ensures that legumes get enough nitrogen without the use of nitrogen fertilizer. The development of the nodule and the biomass are improved by 25–40% by the 1-aminocyclopropane-1-carboxylate deaminase enzyme generated by microbial strains. This enzyme destroys ACC, an immediate precursor to ethylene, before it is transformed. Together with the N2-fixing blue-green alga Anabaena azollae, azolla has the capacity to fix atmospheric nitrogen. When it comes to providing nitrogen to rice, Anabaena azollae is said to be the most effective biofertilizer. It is mostly employed for wetland rice.

Azolla is being used mostly in South East Asian rice-growing regions as an alternative nitrogen source to synthetic nitrogen fertilizers. It is thought to be able to fix 40–60 kg of nitrogen per hectare of rice crops. Furthermore, it has been reported from Vietnam that a 10-ton covering of Azolla increases rice output over equivalent Azolla-free rice fields by 10–25%. An essential aerobic nitrogen fixer is Acetobacter. It is a crucial sugarcane inoculant. Basically, it colonizes the roots of many sugarcane species. Additionally, it collaborates well with coffee. It is also well-known for producing indole acetic acid and gibberellic acid, which encourage development and increase the number of rootlets, which in turn facilitates the intake of water, minerals, and phosphate solubilization, which fosters sugarcane growth and sugar recovery[3].

Field applications and preparation of commercial biofertilizers

Due to several environmental problems, it is now imperative to promote plant health using sustainable methods, and in this context, biofertilizers are among the most effective instruments for doing so. It is now obvious that biofertilizers are bacteria that play an important role in preserving plant health by fighting against pathogens as well as stimulating development by making a variety of nutrients and phytohormones available. They are also microbes that represent a crucial part of sustainable agriculture. These formulations are made in such a manner that they continue to be effective while also boosting soil fertility and production. Studies demonstrate that the formulations become more active and numerous in the soil after being inoculated into the host plant. Good biofertilizer formulations should have the following desirable qualities. They should be environmentally friendly, that is, they shouldn't harm the environment or be toxic, and they should be biodegradable.

They should also allow for nutrient additions and pH adjustments, be made of inexpensive raw materials that are readily available, have a long shelf life, and be able to maintain metabolically viable high numbers of weeds. Commercial biofertilizers come in a variety of forms, such as liquid biofertilizers, peat formulations, granules, and freeze-dried powders. Recently, liquid formulations have been created, and they are becoming more popular since they are simple to use and can be applied to soil or seeds with ease. Additionally, liquid biofertilizers have many benefits over traditional solid carrier-based inoculants, including longer shelf lives of up to 2 years and purity, ease of application, identification, and maintenance. These formulations enable the manufacturer to add an adequate amount of nutrients as well as a variety of cell protectants and inducers that can aid in the formation of cells, spores, or cysts. In comparison to carrier-based powder, liquid biofertilizers need fewer dosages and have a high export potential[4], [5].

Application method for prepared biofertilizers

Formulated biofertilizers may be incorporated into the soil in a variety of ways, including by inoculating seeds with dry or liquid biofertilizers. Studies conducted both in greenhouses and fields have evaluated the stimulation of plant growth and crop production by beneficial plant growth-promoting microbiomes in an effort to reduce pesticide usage and pollution produced by them. Azospirillum has been evaluated in several research and is ranked first among PGPR. Azospirillum inoculants for maize are offered in South Africa and Europe. Asesora Integral Agropecuaria, S.A. sells a variety of goods in Mexico that are made from the fungus Azospirillum brasilense. For a variety of crops, including wheat, sorghum, barley, and maize. Numerous businesses are always creating new products based on Azospirillum and other helpful ingredients. Azospirillum has produced a variety of favorable outcomes, however it is said that there are still certain barriers to its commercialization, which may be caused by differences in field trial findings. The inconsistent outcomes may be due to a variety of reasons, such as the inability of the inoculation strain to colonize the roots of the plant and the physical and chemical conditions of the soil, such as pH changes. Furthermore, environmental variables like changing temperatures or little rainfall throughout the growth season may also be a cause in these inconsistent outcomes.

Biofertilizers' Potential Biotechnological Function

Biofertilizers' function in Photosynthesis

Because nearly 90% of plant biomass is produced by absorption of CO2, photosynthesis rate affects how well plants develop. According to reports, when rice was infected with certain Rhizobia strains, a significant improvement in the plant's total photosynthetic rate was seen. Reactive oxygen species are produced when there is a water shortage, which harms the photosynthetic machinery. Under water stress, Heidari and Golpayegani investigated the effects of Pseudomonas sp., Bacillus lentus, and Azospirillum brasilens on basil plants' ability to photosynthesize and their antioxidant activity. According to the research, these strains increased the amount of antioxidant and photosynthetic pigments as well as chlorophyll in the leaves, which reduced the effects of water stress. When potato was inoculated with Bacillus sp. under salt, drought, and heavy metal stresses, observed a positive effect on the plants' PSII photochemistry as measured by the photosynthetic performance indices of the inoculated plants. By inoculating mutant Arabidopsis thaliana aba2-1 and Col-0 plants with the

Azospirillum brasilense Sp 245 strain under both well-watered and dry circumstances, Cohen et al. examined the morphophysiological and biochemical reactions. Along with other measurable characteristics, the strain induced the synthesis of photosynthetic and photoprotective pigments. Thus, by enhancing the photosynthetic apparatus, biofertilizers may simply aid in the survival and development of plants under stress.

Biofertilizers' role in the production of Amino Acids

The roots of plants provide a variety of vital functions, including mechanical support, nutrient and water absorption facilitation, and the synthesis of chemicals like amino acids, which further draw in a diverse and heterogeneous community of microorganisms. The composition of these root exudates, which alter the physicochemical characteristics of the soil, is dependent on the kind of plant and the soil's accompanying bacteria.

As a result, the kind of amino acids released by plant roots varies significantly depending on the difference in adherent PGPR population. 5.3. Metals, which act as micronutrients, are essential for plant development in bioremediation biofertilizers. However, because of ongoing human activity, extensive agricultural production, and rapid industrialisation, a lot of contaminants, including heavy metals, are released, eventually creating serious environmental issues. The main inorganic pollutants accumulating in the soil biosphere are heavy metals and other elements, and one of their distinguishing characteristics is non-degradability.

Many chemical, physical, and biological techniques have been used to purge the environment of these toxins, but bioremediation is recognized as the most effective and promising way. There are diverse plant growth promoting rhizobacteria and soil microbiomes including Achromobacter, Azotobacter, Bacillus, Bradyrhizobium, Brevibacillus, Kluyvera, Mesorhizobium, Ochrobactrum, Pseudomonas, Psycrobacter, Ralstonia, Rhizobium, Sinorhizobium, Variovox, and Xanthomonas which have been used for remediation of these contaminants. The synthesis of ACC deaminase, which lowers ethylene content in plants and offers an effective protection to the host plant against stress brought on by heavy metal and other element toxicity, is one of the defensive mechanisms used by PGPR. Production of iron chelating substances known as siderophores, which have been described in rhizospheric bacteria of the genera Bradyrhizobium, Pseudomonas, Rhizobium, Serratia, and Streptomyces, is another effective defensive mechanism used by PGPR[6].

Using biofertilizers to Remove Insecticides

Pesticides are often employed in contemporary agriculture to control pests economically, but overusing them puts the environment and the plant kingdom in danger since they may enter living tissues. Finding some eco-friendly solutions for pest control is thus crucial. To counteract the negative effects of pesticides, much study is being done on the bacteria that break down pesticides. Toxicities caused by pesticides can be reduced by strains of bacteria from the genera Azospirillum, Azotobacter, Bacillus, Enterobacter, Gordonia, Klebsiella, Paenibacillus, Pseudomonas, and Serratia. Actinomycetes have also been implicated in the biotransformation and biodegradation of pesticides in some studies. Esterases and hydrolases are only a few of the important lytic enzymes that microbes create. Different chemical reactions, such as addition, dehalogenation, hydrolysis, metabolism of side chains, oxidation, reduction, and ring cleavage, have been reported which ultimately reduce the toxicity of pesticides.

These include mixed function oxidases and the glutathione S transferases system. Thus, it is evident that using plant growth-promoting microorganisms to decontaminate soil from pesticides might be an effective strategy [7].

Biofertilizers' role in Reducing Abiotic Stress

At any one moment, plants are subjected to a variety of biotic and abiotic stressors, which change their physiological states and disrupt their metabolic rhythms, leading to abnormal physiology. Stress causes plants to produce an excessive amount of ROS. These stress-induced species comprise free radicals and non-radical molecules such H2O2, which disrupts plant senescence processes and damages cells and causes metabolic problems. There are other PGPRs that assist plants in overcoming these stressors via various processes, such as the formation of glycine betaine, which defends against water scarcity while also defending against salinity and freezing.

Rhizobacteria create a variety of osmolytes, including as proline, glycine betaine, trehalose, and ectoine, under drought stress to maintain cytoplasmic osmolarity. Numerous membrane-derived oligosaccharides found in the periplasm of bacteria help to keep the turgor pressure of the periplasm constant. Numerous bacterial species, including Pseudomonas alcaligenes, Pseudomonas aurantiaca, Pseudomonas aureofaciens, and Pseudomonas chlororaphis, have been shown to generate plant growth regulators and aid in the development of various crops in harsh environments. PGP soil microorganisms that produce cytokinin that are isolated from rhizospheric soil encouraged plant development and reduced heat stress in plants.

The cytokinin-producing Bacillus subtilis boosted growth and demonstrated drought stress tolerance in Platycladus orientalis. The drought-tolerant endophytic bacterial strains Bacillus pumilus and Achromobacter xylosoxidans demonstrated salicylic acid synthesis in the research. It has been shown that the inoculation of strains under water stress circumstances improves sunflower growth indices. Another study by Lavania and Nautiyal revealed that the halophilic bacterium Serratia marcescens produces salicylic acid. The strain improved growth characteristics and nutrient absorption by colonizing the rhizosphere of maize.

Under controlled conditions, this strain also reduces the effects of salt stress on crops. IAA has been found to be produced by salt-tolerant bacteria such Stenotrophomonas rhizophila, Pseudomonas extremorientalis, P. fluorescens, Serratia plymuthica, and Pseudomonas extremorientalis. In compared to the control, cucumber plants inoculated with these strains significantly increased dry weight by up to 62%, and they also improved fruit output under controlled circumstances. Demonstrated that wheat treated with PGPR under drought stress had 78% more biomass than untreated plants. Demonstrated an increase in biomass and changes to the root architecture that were brought about by the PGPR strain of Phyllo bacterium brassicacearum, which contributed to the observed drought resistance[8], [9].

CONCLUSION

There has been significant progress made globally in the use of PGP microorganisms as biofertilizers and bio pesticides. Direct interactions between the various microbial kinds lead to a number of important activities that eventually improve the health of the soil and plant development. The idea of a microbial consortium for the PGP has recently been floated and may be a workable plan for improving the activity and viability of PGPMs. However, the widespread use of PGP microorganisms will need addressing numerical concerns. Starting with how to culture and store these microbes, as well as the right facilities for transporting, manufacturing, and applying these microorganisms, among other things, will be necessary when transitioning from laboratory and greenhouse to field trials. Second, it would be crucial to dispel the widespread notion that microorganisms are the root cause of illness by educating the public about the widespread use of these microbes in agriculture. Therefore, before these helpful bacteria may be employed extensively in the environment, these myths must be dispelled.

Additionally, the plants are exposed to a variety of infections, which results in crop loss. To prevent disease, chemical pesticides are used, but they have a number of negative effects on the environment and human health. In order to feed the growing population, it is necessary to find alternative strategies that are environmentally friendly. In the future, biofertilizers will not only act as a potential replacement, but will also increase productivity and support plant growth under stressful conditions. Therefore, it is vital to understand the value of biofertilizers and how they are used in contemporary agriculture. Instead of producing plants, sustainable agriculture should focus on cultivating plant-microbial communities, which would eventually result in high production with little energy and chemical expenditures while putting the least amount of burden on the environment. However, as this process is still in its early stages, much more work and cooperation between specialists in plant and microbial genetics, molecular biology, and ecology are still necessary to achieve sustainable microbial-based agro technologies.

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CHAPTER 25

MANAGING MICROBIAL BIOFERTILIZERS IN THE RHIZOSPHERE FOR SUSTAINABLE AGRICULTURE

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ABSTRACT:

Given the limited availability of soil nutrients and fertility and the rising global population, guaranteeing food security is becoming more difficult. To fulfill the expanding population's need for food, agricultural production must be raised. The ecological balance and human health have been harmed by a strong reliance on chemical fertilizers, which is becoming too costly for many farmers to sustain. One possible answer to this problem is the use of advantageous soil microorganisms in place of artificial fertilizers in the production of food. In the agricultural industry, microbes like plant growth-promoting rhizobacteria and mycorrhizal fungi have proven their aptitude in the creation of biofertilizers, which give plants the nutrients they need to improve growth, increase yield, manage abiotic and biotic stress, and ward off phytopathogen attacks. The recent discovery of some volatile organic compounds produced by advantageous soil microbes that are helpful to plants is being used to create biofertilizers, which boost plant productivity by combining these microbes with organic materials and nanoparticles that are currently available locally. This study focuses on the crucial function played by advantageous soil microorganisms as a practical, affordable, non-hazardous, and environmentally acceptable method for managing the rhizosphere to increase plant output.

KEYWORDS:

Beneficial Microorganisms, Biofertilizers, Crop Production, Soil Fertility, Sustainable Agriculture.

INTRODUCTION

By 2050, the world's population is projected to reach more than nine billion, representing a third more people to feed than it does now, according to the Food and Agriculture Organization of the United Nations. Therefore, to guarantee food security, agricultural productivity must be greatly increased by regulating the rhizosphere in a short amount of time. In order to achieve this aim, certain criteria must exist, such as the ideal environmental circumstances and the availability of rich soil conditions, which are becoming scarcer over time. Chemical fertilizers have aided in feeding the world's population since the middle of the 20th century. This has been accomplished by giving plants the necessary nutrients, such as phosphorus, nitrogen, and potassium. NPK fertilizers are used to enhance the amount of nutrients required for plant development and crop performance on an annual basis in amounts of around 53 billion tons. Unfortunately, plants only use a tiny portion of these nutrients; a larger portion is precipitated by soil-based metal cations. The case for the adoption of agricultural techniques that do not affect the environment is strengthened by the fact that the large and improper use of chemical fertilizers causes environmental problems that are of great concern to farmers. Scientists from all around the world are starting to focus their research on employing beneficial soil microbes instead of synthetic fertilizers and pesticides to ensure the sustainability of agriculture[1].

Rhizosphere management is the practice of increasing the amount of nutrients available to plants in the soil in order to promote plant development and increase plant output. Beneficial soil microorganisms improve rhizosphere management via a variety of multifaceted processes. These include the synthesis of siderophores, nitrogen fixation, lytic acids, hydrogen cyanide, phosphate solubilization, and indole acetic acid, among others. The methods by which these advantageous microbes function are essential for enhancing soil fertility, plant development, and yield.

In order to regulate the rhizosphere and increase plant output, several strains of helpful soil microbes have been identified [9] and are being exploited in biotechnology as instruments to increase food security and agricultural sustainability. Mycorrhiza fungi and rhizobacteria that promote plant development are now thought of by soil scientists as microorganisms that play crucial functions in ensuring that nutrients are available in the soil to promote plant growth and boost yield. Since using biofertilizers to increase agricultural yield and soil fertility is both economical and ecologically beneficial, it is becoming more popular. Microbial biofertilizers are made up of living, plant-growth-promoting microorganisms that interact with the rhizosphere or endosphere of plants to boost yield by enhancing soil fertility and encouraging nutrient absorption. Utilizing biofertilizers lowers the high cost of chemical fertilizer purchases and satisfies global demand for environmentally friendly agricultural production methods. The control of the rhizosphere to enhance plant development and production via the use of PGPR and mycorrhizal fungi in the creation of economical and environmentally responsible microbial biofertilizers is the main emphasis of this study[2].

DISCUSSION

Rhizobacteria that Promote Plant Growth

PGPR are organisms that live in close proximity to plants and plant tissues. They may boost a plant's ability to withstand biotic and abiotic stress as well as increase nutrient intake and phytohormone levels in tissues. Even bacteria with different evolutionary histories could use comparable strategies to increase plant production. A variety of PGPR samples and their underlying mechanics. The genera Rhizobium, Bradyrhizobium, Bacillus, Azospirillum, Azotobacter, Acinetobacter, and Pseudomonas include some of the most well-known PGPR.

A Mycorrhizal Fungus

Mycorrhiza is a word used to describe a symbiotic relationship between plant roots and certain fungus. Depending on the kind of plant and fungus involved in the mycorrhiza connection, the fungi invade the plant root either intracellularly or extracellularly. According to a straightforward interpretation, the relationship between a host plant and fungus can be described as reciprocal in that the host plant provides the fungus with the carbohydrates it needs for its metabolic processes, and the fungus, in turn, provides the host plant with the nutrients and water it needs for growth. Therefore, the relationship between the fungus and the host plant is symbiotic and mutually beneficial. The absorption of water and nutrients from the soil, such as phosphorus, which is necessary for plant development and production, is facilitated by mycorrhizal fungus. The inorganic phosphate transporter in Glomus versiformis mycorrhizal hyphae has also been shown to improve phosphate uptake by the host plant. Additionally, mycorrhizal fungus may make it easier for organic and inorganic soil contaminants that might impair plant production to be detoxified[3].

There are two main categories of mycorrhizal fungi: ectomycorrhiza, which is typical of trees and shrubs but also occurs in more than 86% of plant species, and endomycorrhiza, in which hyphae do not penetrate plant root cells but instead form intracellular arbuscules. The "Common Symbiotic Pathway," a mycorrhizal protein high in cysteine, is essential for aiding the contact between mycorrhizal fungus and host plants, and it is how the mycorrhiza is established.

Various Types of Microorganisms Used to Produce Biofertilizers

Microbes that Fix Nitrogen

The greatest symbiotic nitrogen fixers are known to dwell in the plant root tubes and are members of the family Rhizobiaceae, which is made up of many genera, including Rhizobium, Azorhizobium, Bradyrhizobium, Mesorhizobium, and Sinorhizobium. Leguminous plants' rhizobium binds atmospheric nitrogen in the root tube. The plant uses nitrogen to create several nitrogenous substances, including amino acids, vitamins, and nucleic acids. The same enzyme, nitrogenase, is used by all bacteria that fix nitrogen. Leguminous plants are less reliant on the use of artificial nitrogen fertilizers because to the role Rhizobia play in nitrogen fixation, which is also the secret to the crop rotation strategy's effectiveness in sustainable agriculture.

Low nitrogen availability promotes nodule development, however microorganisms that make the enzyme 1-aminocyclopropane-1-carboxylate deaminase may also contribute to nodule formation by degrading 1-aminocyclopropane-1-carboxylate before it is converted to ethylene. Due of oxygen's inhibitory influence on nitrogenase activity, leguminous plants and Rhizobiaceae bacteria have established a similar approach to reduce the concentration of oxygen to which the nitrogenase is exposed. Other nitrogen-fixing bacteria, including those in the Acetobacter genus, can fix nitrogen even when the environment is aerobic.

It is possible for certain Azotobacter strains to invade the roots of plants like sugarcane, coffee, cotton, wheat, rice, and vegetables. When wheat plants are co-inoculated with certain strains of Azotobacter and Pseudomonas, compared to inoculated plants, grain yield, protein content, and harvest index rise, allowing the use of chemical fertilizer in the field to be reduced by 25–50%. A genus of nitrogen-fixing bacteria that can fix nitrogen in aerobic environments and function as a biocontrol agent is called Azotobacter. Fungicide characteristics have been associated with Azotobacter indicum. Numerous Rhodospirillaceae species of Azospirillum have been discovered in association with grass rhizospheres while fixing nitrogen. By altering the cell wall flexibility or the root shape, or both, by triggering changes in phytohormone production, plant inoculation with Azospirillum strains enhances plant growth and yield.

Microbes that Solubilize Phosphorus

One macronutrient that drastically restricts plant growth and production is phosphorus. The majority of the time, phosphorus is present in the soil as phosphate, which may be either organic or inorganic and is present in high quantities. The bulk of inorganic phosphate is trapped as insoluble salts, and only a little portion of it is accessible to the biosphere in the soil solution. Some species of Pseudomonas, Cyanobacteria, and Bacillus isolated from plant rhizospheres have shown evidence of phosphorus solubilization, which includes local acidification or alkalinization[4].

The main source of phosphate in soil is organic, but since these molecules are often complex, microbes must break them down before plants can absorb them. As a result, enzymes like phosphatases and phytases are produced during the mineralization of phosphorus in the soil. Some Pseudomonas, Cyanobacteria, and Bacillus species have the ability to mineralize and solubilize phosphate.

Microbes that Solubilize Potassium

Amylases, which are involved in the coordination of the root-to-shoot ratio, are only one of the numerous enzyme activities that potassium regulates. A lack of potassium results in poor root development, an increase in the plant's vulnerability to diseases, and a decrease in plant growth and output. Many investigations have identified many soil-dwelling bacteria that may dissolve potassium. These include a few bacteria including Bacillus mucilaginous, Azotobacter chroococcum, and Rhizobium spp. that have been linked to higher maize, chili, cotton, pepper, sorghum, and wheat production by potassium solubilization. The inoculation of wheat with a Bacillus edaphicus strain that solubilizes potassium was recently found to have significantly increased root and shoot development when compared to uninoculated plants. Because potassium-solubilizing microorganisms produce organic acids as one of their processes, using them in agriculture is the greatest way to increase soil fertility and promote plant yield. The absorption of potassium, plant yield, and growth are all increased when plants are inoculated with bacteria that make potassium soluble.

Microbes that Mobilize Phosphorus

Some genera of endomycorrhizal fungi are already used as biofertilizers, and they play a significant role in increasing phosphorus bioavailability. The mycorrhizal plant root system can effectively explore a larger soil volume than non-mycorrhizal plants because the fungal hyphae can enter the soil pores, places where the root system cannot reach. Glomus mosseae has recently been used as a biofertilizer and has been shown to boost wheat shoot length, root dry weight, and root length. Mycorrhizal hyphae have also been shown to promote soil structure. When compared to the expense of purchasing chemical fertilizers, the use of mycorrhizal fungus in agriculture boosts plant output while being inexpensive, environmentally benign, and has no adverse effects on the environment. Tillage and the use of chemical fertilizers or pesticides, however, have a detrimental impact on the beneficial function that arbuscular mycorrhizal fungi play in plants. With their function in enhancing plant health, production, and soil fertility, arbuscular mycorrhizal fungi are being used more and more often to ensure sustainable agriculture.

Biofertilizers' Positive Effects on Plant Yield, Photosynthesis, and Soil Nutrient

Biofertilizers are products made of healthy microbe strains that are used to boost plant development without endangering people or the environment. Nitrogen-fixing bacteria, phosphorus solubilizing microbes, sulphur solubilizing microbes, mycorrhizal fungi, and potassium solubilizing microorganisms are a few examples of the microorganisms employed in the manufacturing of biofertilizers that may boost plant growth and productivity.

The impact of Rhizobium leguminosarum and other Rhizobium species has been recently discovered. Bradyrhizobium species and IRBG 74. Compared to uninoculated plants, IRBG 271 boosts plant biomass, yield, and chlorophyll content. The IRBG strains produced the largest rise, which was 14% higher than that of uninoculated plants. Similar to Rhizobia, inoculated plants may benefit from increased surface area, photosynthetic rate, water absorption capacity, yield, and stomatal conductance when exposed to particular Rhizobia strains.

The application of biofertilizers to spinach has been shown to increase growth, chlorophyll content, antioxidant activity, yield, and phenolic compounds in plants. In addition, inoculation of a group of bacteria, including Pseudomonas, Bacillus lentus, and Azospirillum brasilense, was reported to increase chlorophyll content in plants. When compared to spinach that had not been infected, the total phenolic compounds were said to be 58% greater. Similarly, inoculating lettuce with Azotobacter chroococcum and Piriformospora indica led to an increase in growth, yield, phenolic compounds, anthocyanins, and carotenoid content. The process through which arbuscular mycorrhizal fungus produce antioxidants. Similarly, inoculating soybeans with nitrogen-fixing Rhizobium and Bradyrhizobium led to an 80% increase in production. Following inoculation with Glomus mosseae, Trichoderma viride, and Bacillus coagulans, it was also noted that Begonia malabarica and Calamus thwaitesii produced secondary metabolites such as tannins, ortho-dihydroxy, and flavonoids.

The use of biofertilizer has also been linked to its influence on boosting plant growth and yield for increased food production. This is clear from study that found enhanced maize production when biofertilizer derived from plant growth-promoting Actinomycetes was used. Data collected for the research showed that the biofertilizer generated from a mixture of O19 and AHB12 had the best yield performance, increasing it to 311.5 g for 1000 seeds compared to 178.28 g for the control plant. On two genotypes of forage rice, the impact of biofertilizer created from the plant-growth-promoting Bacillus pumilus strain TUAT-1 has recently been assessed. The result showed that, in comparison to uninoculated rice, rice production was improved by biofertilizer generated from the Bacillus species. The use of biofertilizer in boosting maize growth and yield performance is another. When compared to an uninoculated control, the research found that biofertilizer made with phosphate-solubilizing bacteria improved maize growth and yield[5], [6].

More crucially, a variety of soil processes including runoff, bush burning, and leaching of agricultural soil deplete the nutrients in the soil. Rainfall-induced runoff carries soil nutrients to the water body, where they contribute to eutrophication and pollution. The natural environment is severely threatened as a result of this. Thus, it is crucial to recover soil nutrients to improve plant growth and yield performance by applying nutrient-rich biofertilizer made from microorganisms that promote plant growth and have the potential to do things like fix nitrogen, solubilize potassium, and solubilize phosphate.

Because the population of native mycorrhiza fungi in the soil has been decreased by the use of chemical fertilizer, inoculating crops with mycorrhizal fungi as biofertilizers is now becoming increasingly popular. However, it is crucial to choose high-quality mycorrhizal fungus when choosing the right ones since they can colonize plant roots, function in the presence of bacteria, and have a long shelf life in the field and greenhouse. Arbuscular mycorrhizal fungi may be multiplied most easily by employing a suitable host plant and sterile soil to propagate a viable spore. This calls for growing inoculated host plants in sterile soil and allowing arbuscular mycorrhizal fungus spores to mature and spread within the host plant. This process of creating inoculum is known as "soil-based inoculum," and it is the technique most often employed to multiply arbuscular mycorrhiza spores.

Arbuscular mycorrhizal fungi must be employed successfully, and this relies on the strain, host plant, and propagation medium. Sorghum and maize are host plants that are often utilized in the multiplication of arbuscular mycorrhizal fungi because of their high mycorrhizal fungus infectivity. Mycorrhizal fungi are found in the soil and roots, which are gathered throughout the growth cycle, dried, and utilized as an inoculum.

Nanoparticles have recently been added to plant growth-promoting microorganisms in the composition of biofertilizer, a novel technological advancement. This method uses nanoparticles that are at least 100 nm in size and may be constructed of organic or inorganic materials. This method is known as the agro-nanotechnology strategy in agriculture. To improve plant yield performance, plant growth-promoting microorganisms are included into the nanostructure. Due to the direct and indirect effects of nanomaterial coating on plant growth-promoting microorganisms, the formulation of nano-biofertilizer has effectively increased agricultural productivity by increasing high retention in soil moisture content and increasing essential nutrients. Its application has also been reported to increase yield performance in cereal and leguminous plants by stimulating the germination potency in plants.

Biofertilizer Formulations: Types and Uses

Liquid and solid versions of biofertilizers are also available. In liquid formulations, a culture of microorganisms is combined with other substances, such as water, oil, and other additives, to assist the prepared product adhere and disperse more readily. Liquid formulations have the significant benefit of being simple to manufacture and having low manufacturing costs. The carrier-based formulation, also known as the solid formulation. It is a biofertilizer formulation that is performed as granules or powder and is based on the presence of either an organic or inorganic carrier. The organic or inorganic carrier, which may be in the form of a powder or granular product, is the most crucial ingredient in the formulation of a solid biofertilizer[7], [8].

The kind of bioformulation to be administered determines how biofertilizer should be applied. Biofertilizers may be administered in a number of ways, including seed inoculation, root dipping, and soil treatment with either dry or liquid biofertilizers. In seed inoculation, a slurry of carrier biofertilizers and water is used. Sterile seeds are combined with the inoculants within the slurry to create a homogeneous coating on the seed, and the combination is then air-dried prior to seeding. For the application of biofertilizer to transplanted crops, the root dipping technique is utilized. Before the plant is transplanted, the root is briefly submerged in a combination of the biofertilizer and water. Biofertilizer may also be used as a foliar spray when it is sprayed as a soil amendment at a certain time when the farmer is prepared to sow the seed.

The Impact of Biofertilizers on Amino Acid and Volatile Organic Compound Production

One of the metabolic processes carried out by advantageous bacteria that are employed as a signal of interaction between plants and microorganisms to increase plant development and yield is the formation of volatile organic molecules. VOCs, which include acetone, 3-butanediol, terpenes, jasmonates, and isoprene and are categorized as natural substances that may increase plant productivity, are produced by several plant growth-promoting microbes and plants. Inhibiting the impact of phytopathogens on plant production and affecting systemic resistance in plants are both achieved via the use of VOCs, which are generated by PGPR. The influence of many bacterial taxa, including Bacillus, Pseudomonas, Arthrobacter, and Serratia, on the production of VOCs and their beneficial effect on enhancing plant productivity was studied by Bailly and Weisskopf.

Recently, it was shown that Bacillus species create two volatile organic compounds (VOCs), acetoin and 2, 3-butandiol, which may suppress fungal infections and promote plant development. Similar to this, Pseudomonas fluorescens SS101's generation of 1-3-tetradecadien-1-ol, 2-butanone, and 2-methyl-n-1-tridecene, which may increase plant yield.

Plants have been shown to develop systemic resistance and increase their tolerance to biotic and abiotic stress as a result of bacteria producing VOCs. Additionally, that co-inoculation of PGPR strains Pseudomonas fluorescens, Bacillus subtilis, and P. putida SJ04, with multiple plant growth-promoting traits, increased the concentration of the volatile organic compound and total phenolic compound when compared to an uninoculated plant.

In addition to their capacity to improve plants' ability to absorb water and nutrients, plant growth-promoting bacteria may also manufacture and release a variety of substances, including amino acids. Exudates from the plant's roots draw helpful bacteria from the soil to the rhizosphere. The exudation of various chemical compounds from the plant root controls the beneficial soil microorganisms that surround the plant root and the physicochemical characteristics of the soil. As a result, the kind of amino acid and root exudate released by the plant root depends on the bacteria that live there. Therefore, the kind of amino acids, oxalic acids, flavonoids, and coumarins that plants release depends on the fluctuation in the population of microorganisms that promote plant development and stick to the plant.

Biofertilizer's impact on phytopathogens and pest

By using chemical fungicides, insecticides, and herbicides, plant diseases may be managed. One of the most important aspects of contemporary agricultural practice is the deployment of these pesticides in pest control. Their excessive usage, however, endangers the environment, endangers human health, and endangers living things. Because it has the potential to be economical and environmentally benign, using beneficial microbes to manage pests has drawn increased attention. More significantly, research is being done on the use of advantageous microbes to replace pesticides and reduce their adverse effects. Numerous studies have been conducted on plant growth-promoting microbes in an effort to use them as biopesticides to safeguard forests and the environment. When certain microbial strains are used to create biofertilizer to increase plant output, plants are also protected against pathogenic illnesses. This protection occurs either directly by inhibiting the spread of plant pathogens or indirectly by competing with pathogens for nutrients. The usefulness of microorganisms such Azotobacter, Bacillus, Enterobacter, Paenibacillus, and Pseudomonas in lowering pesticide toxicity has recently been reported.

It's interesting to note that the symbiotic relationship between nitrogen-fixing bacteria and a leguminous plant encourages the production of cyanogenic defensive chemicals that shield the plant against herbivore assaults. Plant production is significantly impacted by a number of variables, including phytopathogen attacks. In order to prevent disease assault on plants, it is thus helpful to apply beneficial microorganisms that generate antimicrobial compounds, such as chitinases and -glucanases, in high concentration. When utilized in the creation of biofertilizers, Pseudomonas fluorescens and Sinorhizobium generate chitinase and -glucanases and are able to prevent Fusarium wilt and soft rot in potato caused by Fusarium udum and Erwinia carotovora recently reported using G. intraradices to increase potato output and prevent the potato virus from attacking plant tissue.

Similar to this, Beris and Vassilakos observed that tomato yellow leaf curl Sardinia virus is suppressed by G. mosseae inoculation. By reducing the quantity of iron in the soil near plant roots via the production of siderophores, certain biofertilizers are able to reduce the ability of disease-causing microbes. According to siderophore-producing Pseudomonas and Bacillus may prevent Fusarium wilt in potato and maize. Similar to this, discovered that Pseudomonas aeruginosa was efficient against the common disease that plagues rice in West Africa, bacterial blight, which is brought on by Xanthomonas oryzae and Rhizoctonia solani. According to Rhizophagus irregularis MUCL 41833 injected potato plants have improved plant defense against Phytophthora infestans. This resistance is mediated by ERF3 through the ethylene signaling system of the plant.

Biofertilizer Difficulties

Although the use of beneficial soil microorganisms in the production of biofertilizers to increase plant productivity is gaining popularity and has seen significant success in recent years, they are not yet widely accepted on a large scale due to the difficulty of duplicating their beneficial effects on plants in a natural environment where environmental conditions vary. The biggest obstacles to the use of microbial biofertilizer are a lack of understanding of the value of microbial biofertilizer in terms of the environment among farming communities, insufficient encouragement and promotion of the use of biofertilizer products by agricultural extension workers, a lack of suitable carriers for biofertilizer formulation, a lack of storage facilities to prevent contamination of the biofertilizer product, and extreme weather conditions. Additionally, absence of labeling, such as the identity of the microorganisms employed in the creation of the biofertilizer and the expiration date, might damage the trust in the use of biofertilizer products. Most biofertilizers also function selectively.

CONCLUSION

Based on its renewable, affordable, and environmentally friendly potential to provide sustainable agriculture, the use of microbial biofertilizers is crucial to contemporary agriculture. Importantly, the use of biofertilizer has acquired increasing momentum lately in order to satisfy the need for food production of the global population as an essential part of agricultural practice in improving plant yield. In several poor nations, the use of mycorrhizal fungi and PGPR in the manufacture of biofertilizers for rhizosphere management has been successful and will only increase over time. Additionally, new technology that includes modifying microbes that encourage plant development using nanoparticles comprised of both organic and inorganic materials will continue to draw attention over time.

In conclusion, enterprises that create chemicals that are harmful to human health have been fostered by an overreliance on the usage of chemical fertilizers. Creating ecological imbalances as a result. A high production cost that is out of reach for many farmers in poor nations is added to these disadvantages.

The use of biofertilizers has the potential to significantly boost plant output while being environmentally benign, reasonably priced, and nontoxic. Therefore, the role of microorganisms in boosting plant development and the use of biofertilizer manufactured from live microbial strains in the field are encouraging for effective rhizosphere management in sustainable agriculture.

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